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Technical

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ACETIC ACID

February 1985

Canada

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ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS MANUALS

Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals provide detailed information on chemical substances. This information is intended to assist the reader in designing countermeasures for spills and to assess their impact on the environment. The manual has been reviewed by the Technical Services Branch, Environmental Protection Service, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

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ACETIC ACID

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS

Technical Services Branch
Environmental Protection Programs Directorate
Environmental Protection Service
Ottawa, Ontario

February 1985

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FOREWORD

The Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals were initiated in 1981 to provide comprehensive information on chemicals that are spilled frequently in Canada. The manuals are intended to be used by spill specialists for designing countermeasures for spills and to assess their effects on the environment. The major focus of EnviroTIPS manuals is environmental. The manuals are not intended to be used by first-response personnel because of the length and technical content; a number of manuals intended for first-response use are available. The information presented in this manual was largely obtained from literature review. Efforts were made, both in compilation and in review, to ensure that the information is as correct as possible. Publication of these data does not signify that they are recommended by the Government of Canada, nor by any other group.

ACKNOWLEDGEMENTS

The final version of this manual was prepared by the staff of the Environmental Protection Service who wrote extensive revisions to the text, drafted illustrations and incorporated all comments and additions.

The level of detail present was made possible by the many individuals, organizations and associations who provided technical data and comments throughout the compilation and subsequent review. The draft of this manual was prepared under contract to Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation, and Waterloo Engineering Limited.

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1 SUMMARY

ACETIC ACID (CH_3COOH)

Colourless, watery liquid with a strong vinegar odour

SYNONYMS

Glacial Acetic Acid, Aqueous Acetic Acid, Ethanoic Acid, Ethylic Acid, Vinegar Acid, Methane Carboxylic Acid, Acide Acétique (Fr.)

IDENTIFICATION NUMBERS

UN No. 2789 (glacial and solutions, >80 percent), 2790 (solutions, 10-80 percent); CAS No. 064-19-7; OHM-TADS No. 7216566; STCC No. 4931401 (aqueous), 4931303 (glacial)

GRADES & PURITIES

Glacial, 99.85 percent
Technical solutions, 28, 56, 80, 92 percent

IMMEDIATE CONCERNS

Fire: Combustible

Human Health: Moderately toxic by inhalation, ingestion, and contact

Environmental: Harmful to aquatic life in low concentration

PHYSICAL PROPERTY DATA

State (15°C, 1 atm): liquid
Boiling Point: 117.9°C
Melting Point: 16.6°C
Flammability: combustible
Flash Point: 39°C (CC)
Vapour Pressure: 1.6 kPa (20°C)
Density: 1.0492 g/mL (20°C)

Solubility (in water): soluble in all proportions
Behaviour (in water): sinks and mixes, evolving heat and fumes
Behaviour (in air): vapours form explosive mixtures in air; vapours are heavier than air
Odour Threshold Range: 1-10 ppm

ENVIRONMENTAL CONCERNS

Acetic acid is harmful to aquatic life at concentrations as low as 50 ppm. Acetic acid shows no potential for biological accumulation or food chain contamination.

HUMAN HEALTH

TLV: 10 ppm (25 mg/m^3)

IDLH: 1000 ppm

Exposure Effects

Inhalation: Vapour concentrations over 50 ppm are intolerable, resulting in irritation of eyes, nose, throat and lungs. Causes coughing, nausea, vomiting, and difficult breathing.

Contact: Contact can produce deep burns, skin destruction, skin sensitization, inflammation of the mucous membrane and of the eyelids, and erosion of exposed teeth. Eye contact causes immediate burns and possible permanent damage.

IMMEDIATE ACTION

Spill Control

Restrict access to spill site. Issue warning: "CORROSIVE". Call fire department and notify manufacturer. Eliminate sources of ignition including traffic and equipment. Stop the flow and contain spill, if safe to do so. Avoid contact with liquid and inhalation of vapour; stay upwind of release. Keep contaminated water from entering sewers or watercourses.

Fire Control

Use foam, dry chemical, carbon dioxide, water spray or fog to extinguish. Cool fire-exposed containers with water. Stay clear of tank ends. Avoid getting water inside containers.

COUNTERMEASURES

Emergency Control Procedures in/on

Soil: Construct barriers to contain spill or divert to impermeable holding area. Remove material with pumps or vacuum equipment. Absorb residual liquid with natural or synthetic sorbents and shovel into containers with covers. Neutralize contaminated area with lime and shovel into containers for disposal.

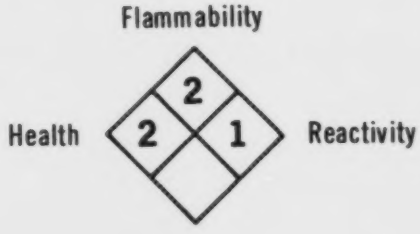
Water: Contain by damming, water diversion or natural barriers. Neutralize with lime or sodium bicarbonate. Remove contaminated water for treatment.

Air: Use water spray to knock down vapour. Control runoff for later treatment and/or disposal.

NAS HAZARD RATING

Category	Rating
Fire	2
Health	
Vapour Irritant	2
Liquid or Solid Irritant	3
Poison	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	2
Aesthetic Effect	2
Reactivity	
Other Chemicals	2
Water	0
Self-reaction	0

NFPA HAZARD CLASSIFICATION



2 PHYSICAL AND CHEMICAL DATA

Physical State Properties (Properties are for pure acetic acid unless stated otherwise)

Appearance	Clear, colourless liquid (Celanese PB 1976)
Usual shipping state(s)	Liquid above 16.6°C (MCA 1951)
Physical state at 15°C, 1 atm	Solid (Celanese MSDS 1979)
Melting point	16.604°C (CRC 1980) 16.75°C (Ullmann 1975)
Boiling point	117.87°C (Kirk-Othmer 1978)
Vapour Pressure	1.57 kPa (20°C) (Ullmann 1975)

Densities

Density	1.0492 g/mL (20°C) (Kirk-Othmer 1978)
Specific gravity (liquid, water = 1) (vapour, air = 1)	1.0492 (20°/4°C) (CRC 1980) 2.07 (Verschueren 1984)

Fire Properties

Flammability	Gives off flammable vapour at high temperatures (NFPA 1978)
Flash point CC OC	39°C (NFPA 1978) 44°C (Celanese MSDS 1979) 57°C (Kirk-Othmer 1978)
Autoignition temperature	464°C (NFPA 1978)
Burning rate	1.6 mm/min (CHRIS 1978)
Upper flammability limit	19.9 percent (v/v) (200°C) (NFPA 1978) 17.0 percent (v/v) (Ullmann 1975)
Lower flammability limit	4.0 percent (v/v) (NFPA 1978) 5.4 percent (v/v) (100°C) (Ullmann 1975)
Heat of combustion	-874.5 kJ/mole (25°C) (CRC 1980)
Combustion products	Carbon dioxide and water (CRC 1980)
Explosiveness	Vapour forms explosive mixtures with air (NFPA 1978)

Other Properties

Molecular weight of pure substance	60.05 (CRC 1980)
Constituent components of typical commercial grade	Glacial: 99.85 percent acetic acid 0.15 percent (max.) water 0.5 percent (max.) acetaldehydes (Celanese PB 1976)

	Others: x percent acetic acid 100 - x percent water
Refractive index	1.36985 (25°C) (Kirk-Othmer 1978)
Viscosity	1.183 mPa·s (20°C), 0.018 mPa·s (40°C) (Kirk-Othmer 1978) 1.2 mPa·s (20 percent at 25°C), 1.7 mPa·s (40 percent at 25°C), 2.1 mPa·s (60 percent at 25°C), 3.1 mPa·s (80 percent at 25°C) (PPH 1984)
Liquid interfacial tension with air	27.57 mN/m (20°C) (Kirk-Othmer 1978)
Liquid interfacial tension with water	38 mN/m (30°C) (CRC 1980)
Latent heat of fusion	11.74 kJ/mole (at melting point) (Ullmann 1975)
Latent heat of vaporization	23.69 kJ/mole (at boiling point) (Kirk-Othmer 1978)
Heat of formation	-484.3 kJ/mole (25°C) (Sussex 1977)
Entropy	159.9 J/(mole·K) (Ullmann 1975)
Ionization potential	10.66 eV (Holmes 1980)
Heat of solution	-1506 J/mole (25°C) (CRC 1980)
Heat capacity	
Constant pressure (C_p)	Liquid: 122.68 J/(mole·°C) (14.4°C) (Ullmann 1975)
	Vapour: 301.99 J/(mole·°C) (124°C) (Kirk-Othmer 1978)
	Solid: 88.77 J/(mole·°C) (1.5°C) (Ullmann 1975)
Constant volume (C_v)	107 J/(mole·°C) (25°C) (CRC 1980; CHRIS 1978)
Critical pressure	5786 kPa (CRC 1980)
Critical temperature	321.6°C (CRC 1980)
Coefficient of thermal expansion	1.071×10^{-3}/°C (20°C) (Celanese PB 1976)
Thermal conductivity	0.158 W/(m·K) (20°C) (Kirk-Othmer 1978)
Saturation concentration	38 g/m^3 (20°C), 63 g/m^3 (30°C) (Verschueren 1984)
Dielectric constant	2.665 (-10°C), 6.170 (20°C) (Kirk-Othmer 1978)

Dissociation constant	1.845×10^{-5} (25°C) (Ullmann 1975)
Specific conductance	0.060 cm^2/ohm (100 percent, 25°C), 2.19 cm^2/ohm (97.60 percent, 25°C), 111 cm^2/ohm (90.75 percent, 25°C) (Kirk-Othmer 1978)
Diffusivity	0.1064 cm^2/s (in air, 0°C), 1.24×10^{-5} cm^2/s (in water, 25°C) (Perry 1973)
pH of aqueous solution	Highly corrosive at dilute concentrations, somewhat less so at glacial strength (MCA 1951). 2.4 (1 N at 25°C) (CRC 1980)
Log_{10} octanol/water partition coefficient	-0.31 (Hansch and Leo 1979)
Evaporation rate	0.45 $g/(m^2 \cdot s)$ (glacial at 20°C, wind 4.5 m/s) (this work)

Solubility

In water	Completely soluble in all proportions (Celanese PB 1976)
In other common materials	Miscible in ethanol and diethyl ether, insoluble in carbon disulphide (Celanese PB 1976). Miscible in acetone and benzene (CRC 1980)

Azeotropes (Ullmann 1975)

Substance	Mass percent Acetic Acid	Boiling Point (°C)
Bromoform	82	118.3
Carbon tetrachloride	1.44	76.6
Heptane	33	91.9
Toluene	34.4	104.8
Cyclohexane	6.5	81.8
Butanol	43.0	120.3
Ethylbenzene	66.0	114.6

Vapour Weight to Volume Conversion Factor

1 ppm = 2.494 mg/m^3 (20°C)

1 mg/m^3 = 0.401 ppm (Verschueren 1984)

Chemical and Physical Properties

In the vapour phase, acetic acid exists as a dimer in the temperature range of 25 to 120°C. The apparent molecular weight is shown in Figure 2. The equilibrium for this is as follows (Kirk-Othmer 1978):

$$(CH_3COOH)_2 \rightleftharpoons 2\ CH_3COOH$$

dimer monomer

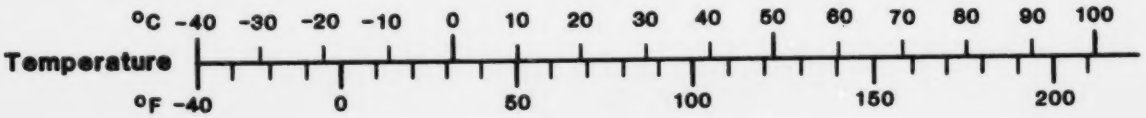
$$\text{Log K dimer} = \frac{3166}{T} - 10.4205$$

As a solid acetic acid also has two forms, the most stable (and common) is known as acetic acid I and consists of orthorhombic crystals. At high pressures (8000 kPa), acetic acid II is formed. Its crystals are monoclinic and are metastable, after formation, down to atmospheric pressures (Wilton 1974).

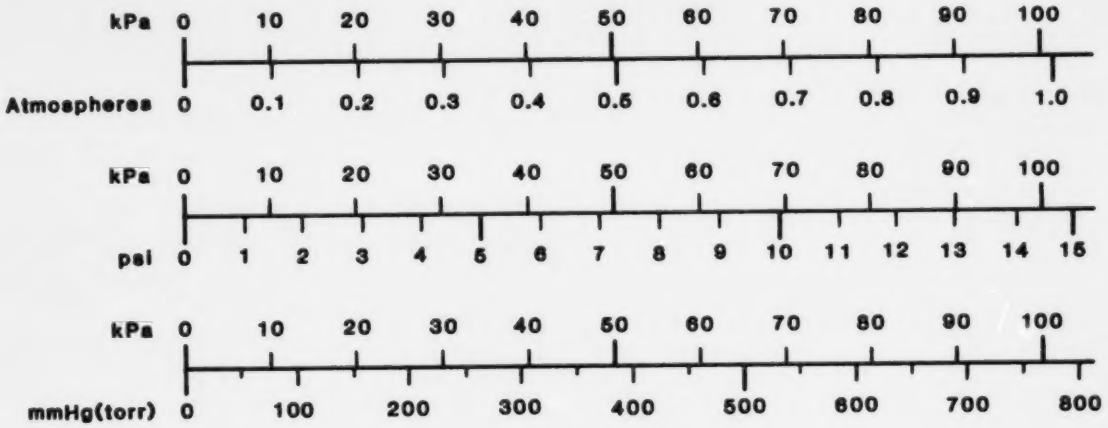
TABLE 1

ACETIC ACID

CONVERSION NOMOGRAMS



Pressure 1 kPa = 1 000 Pa



Viscosity

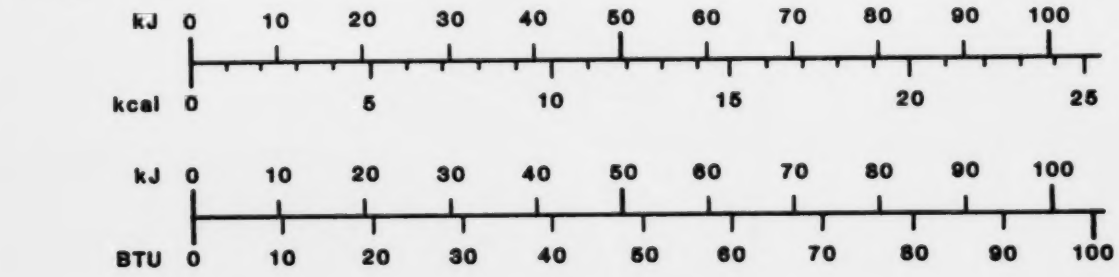
Dynamic 1 Pa·s = 1 000 centipoise (cP)

Kinematic 1 m^2/s = 1 000 000 centistokes (cSt)

Concentration (in water)

1 ppm ≅ 1 mg/L

Energy (heat) 1 kJ = 1 000 J



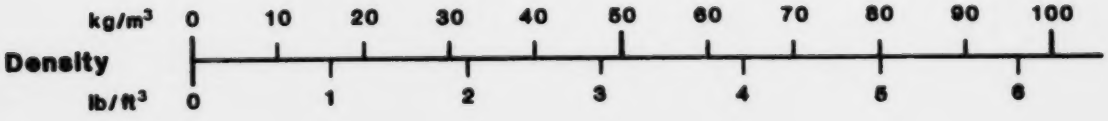


FIGURE 1

ACETIC ACID

VAPOUR PRESSURE

Reference: ULLMANN 1975

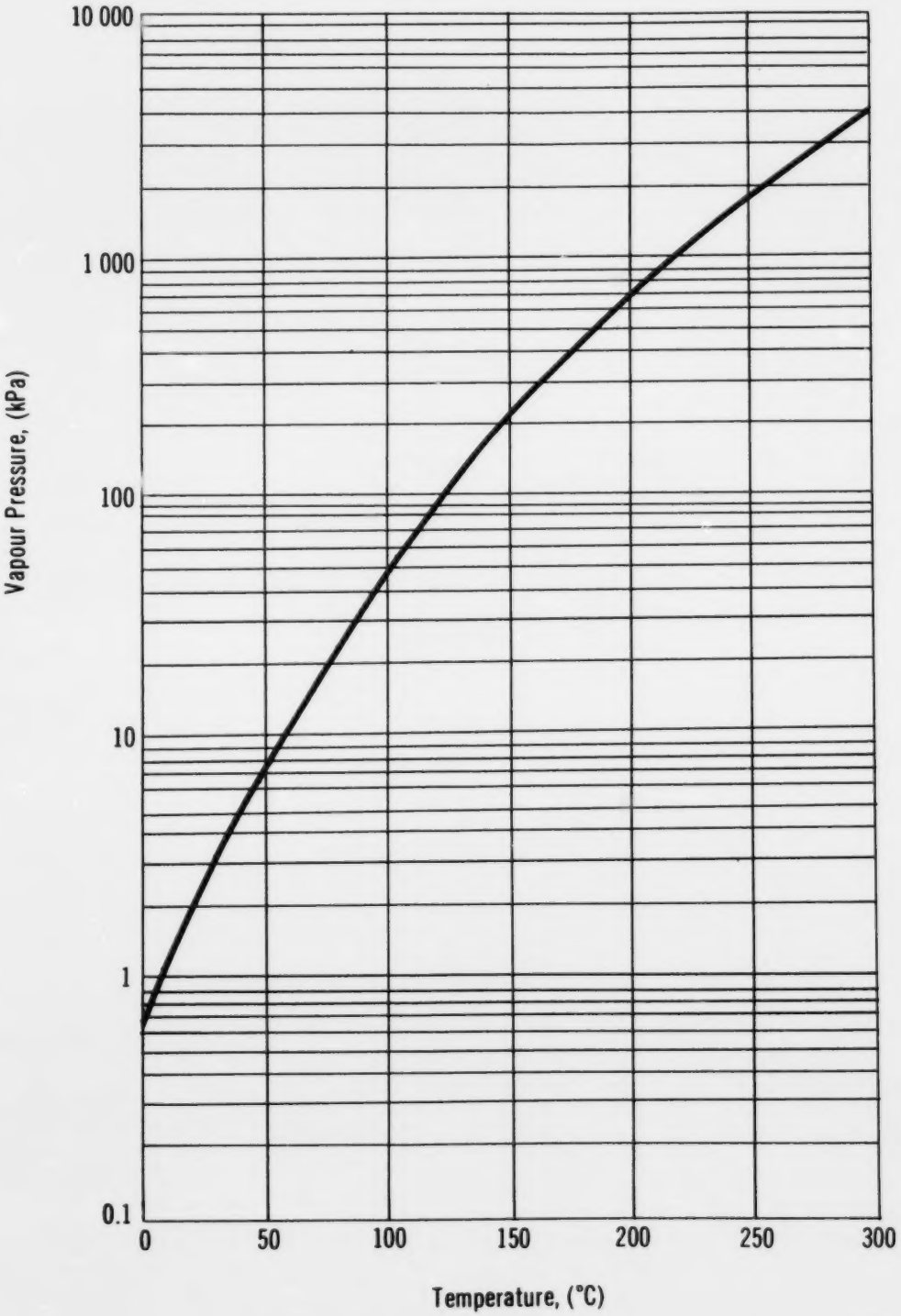


FIGURE 2

ACETIC ACID (VAPOUR)

APPARENT MOLECULAR WEIGHT

Reference: KIRK-OTHMER 1978

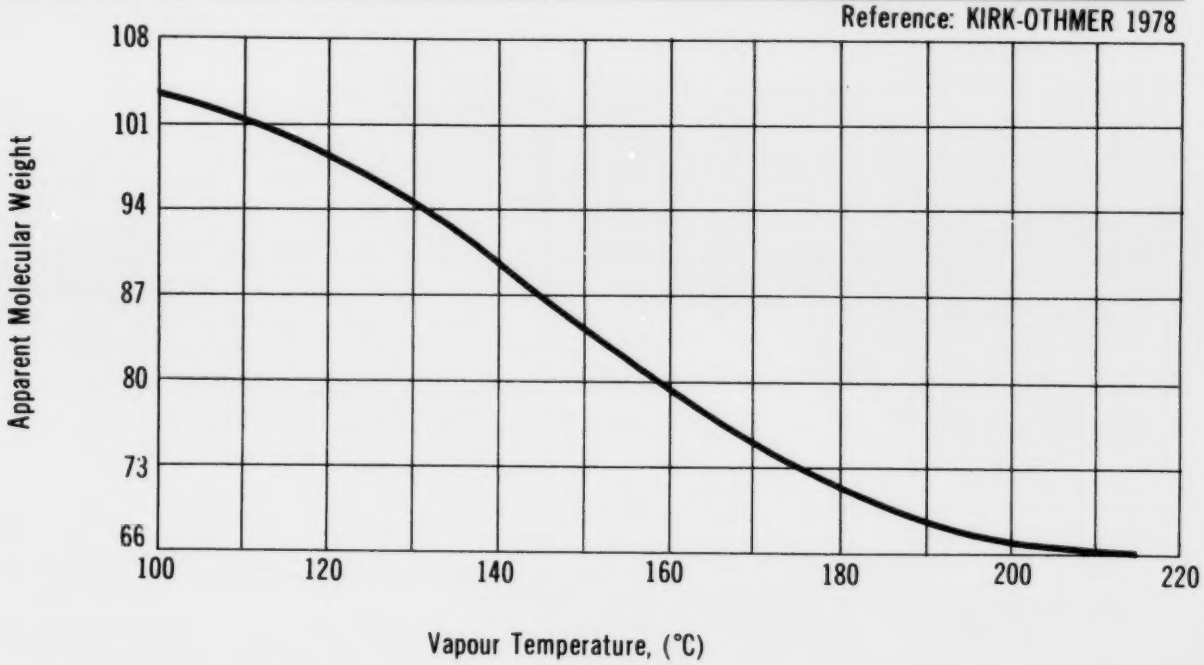


FIGURE 3

ACETIC ACID

FREEZING POINTS OF SOLUTIONS

Reference: ULLMANN 1975

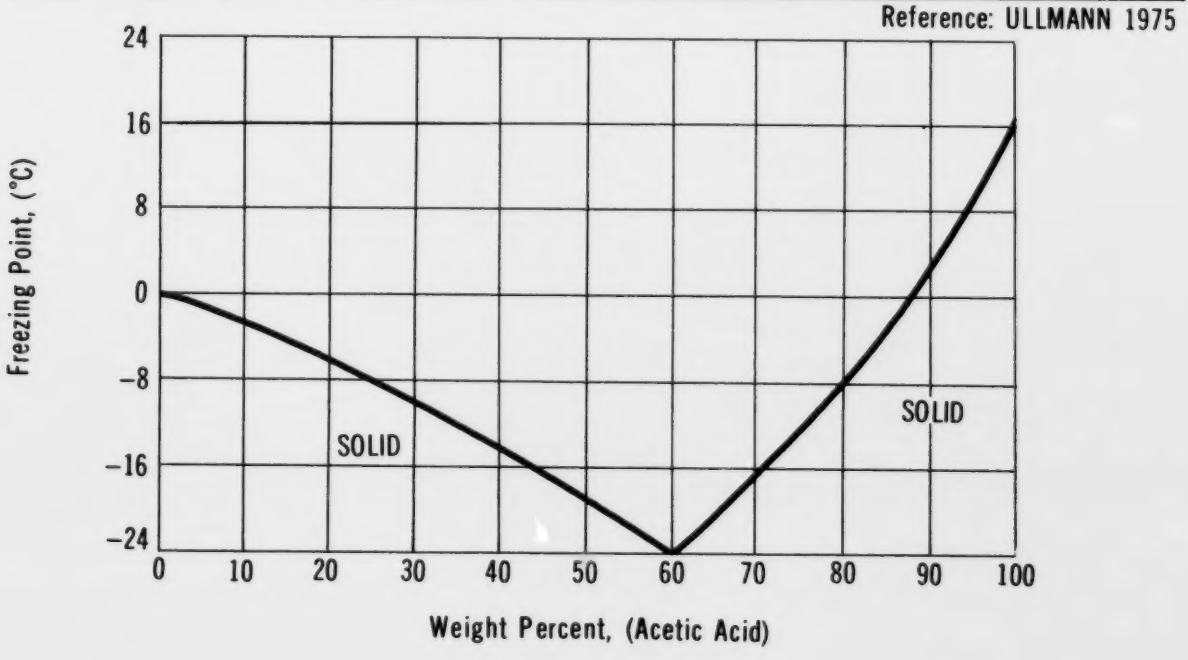


FIGURE 4

ACETIC ACID

DENSITY OF SOLUTIONS

Reference: ULLMANN 1975; PPH 1984

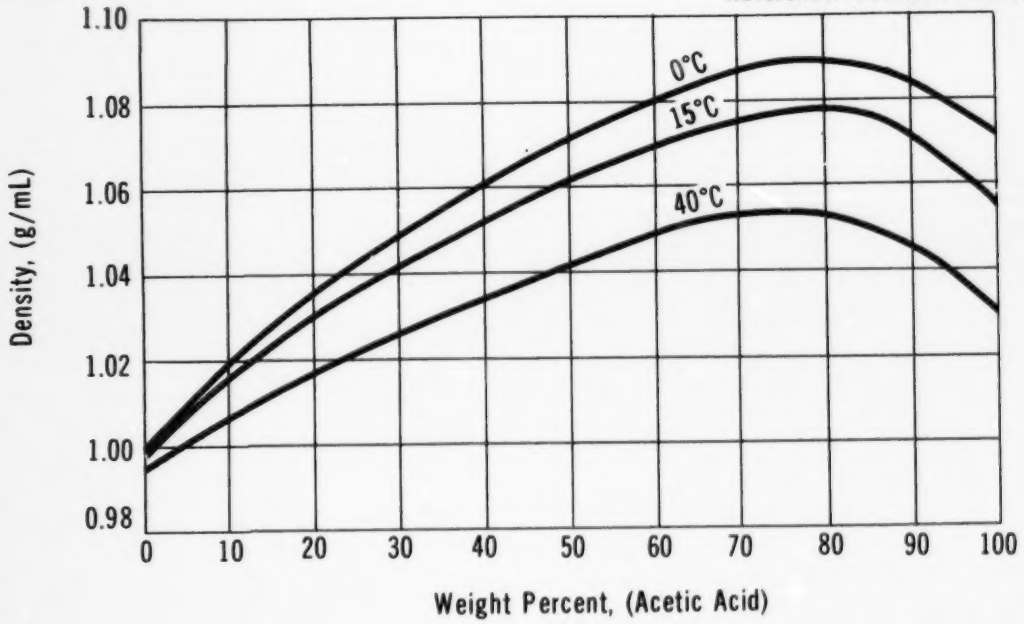


FIGURE 5

ACETIC ACID

VISCOSITY OF SOLUTIONS

Reference: PPH 1984

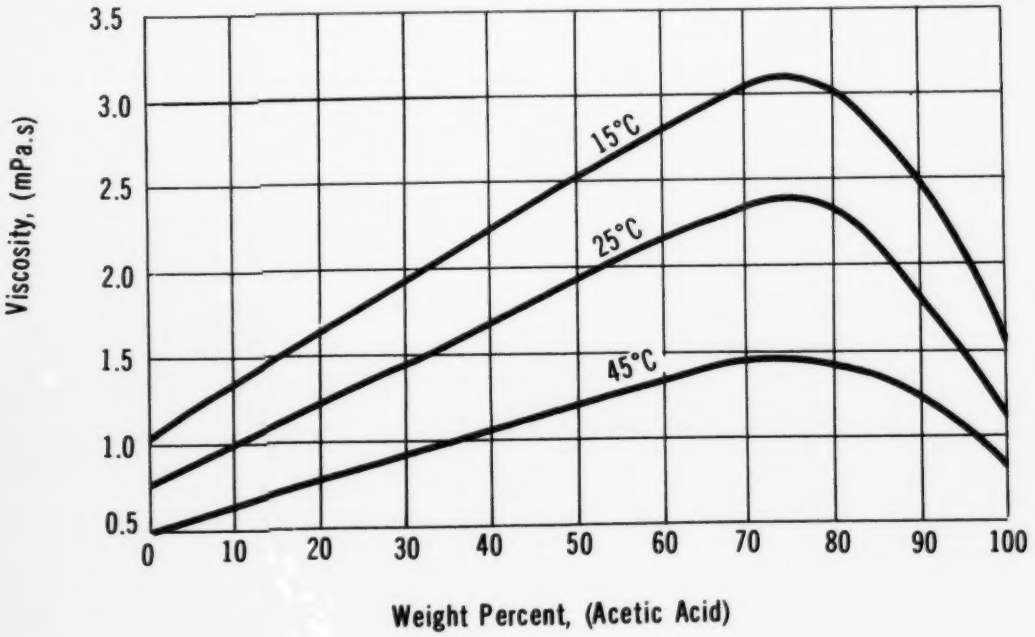
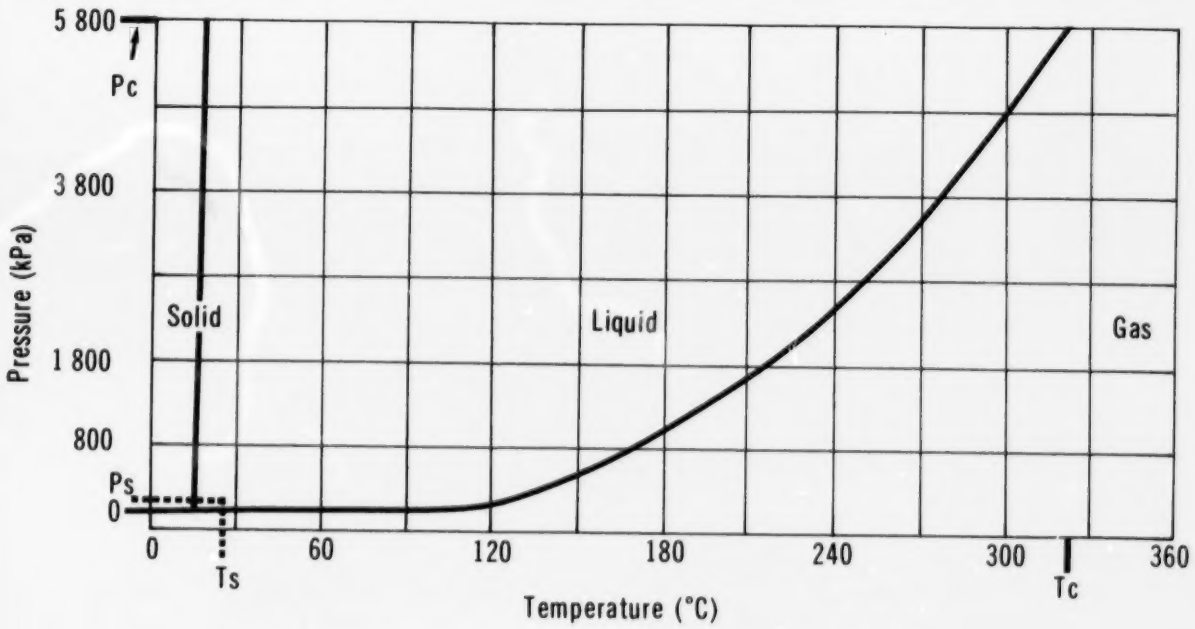


FIGURE 6

ACETIC ACID

PHASE DIAGRAM



3 COMMERCE AND PRODUCTION

3.1 Grades, Purities (Celanese PB 1976; DPIMR 1983)

Glacial acetic acid is available with a purity of 99.5 to 99.85 percent. The technical grade form is available in solutions of 28, 56, 70, 80 and 92 percent.

3.2 Domestic Manufacturer (CBG 1980; Scott 1979)

Celanese Canada Inc.
800 Dorchester Blvd. West
Montreal, Quebec
H3C 3K8
(514) 878-1581

3.3 Other Suppliers (Corpus 1983; CBG 1980)

Henkel Chemicals Canada Ltd.
9550 rue Lawson
Ville d'Anjou, Quebec
H1J 1L3
(514) 353-7550

Ternachem Inc.
310 Victoria Avenue, Suite 101
Montreal, Quebec
H3Z 2M9
(514) 487-2286

Kingsley and Keith (Canada) Ltd.
Four Season's Court, P.O. Box 555
Etobicoke, Ontario
M9C 5B1
(416) 626-8383

3.4 Major Transportation Routes

Current Canadian production of acetic acid is located in Edmonton, Alberta. Small amounts of the product are shipped across Canada.

3.5 Production Levels (Corpus 1983)

Company, Plant Location		Nameplate Capacity kilotonnes/yr (1982)
Celanese Canada, Edmonton, Alta.		72.5
	TOTAL	72.5
Domestic Production (1982)		64.0
Imports (1982)		0.4
	TOTAL SUPPLY	64.4

3.6 Future Developments (Corpus 1983; CCP 1981)

Celanese Canada is planning a 290 kt/yr acetic acid facility in Edmonton, Alberta, to be completed in the late 1980s.

3.7 Manufacture of Acetic Acid (FKC 1975; Kirk-Othmer 1978)

3.7.1 General. Acetic acid is currently manufactured by liquid-phase oxidation of butane. Future plans now exist to construct a large plant using a methanol carboxylation process.

3.7.2 Process. Butane is charged to a reactor at high pressure (1000-5500 kPa, 50-250°C), with a solution of cobalt, manganese, or chromium acetate. Air at 5 kg per kg butane is bubbled through this solution:

$$C_4H_{10} \xrightarrow{(O)} CH_3CO_2H + \text{by-products; (other acids, aldehydes, and carbon oxides)}$$

Acetic acid yield is about 75 percent.

Nitrogen leaving the reactor carries oxidation products and butane; these are condensed and fractionated.

More capacity is planned; this expansion will use methanol and carbon monoxide as feedstock in a methanol carboxylation process. In this reaction, methanol and carbon monoxide are passed over an iodide-based catalyst (nickel iodide, copper or cobalt with iodine, etc.):

$$CH_3OH + CO \xrightarrow{\text{catalyst}} CH_3CO_2H$$

3.8 Major Uses in Canada (Corpus 1983)

Acetic acid is used in the manufacture of cellulose acetate, vinyl acetate, various other acetates, chloroacetic acid, textile processing, and photochemicals. In 1982, 33 percent of domestic production was used for the manufacture of vinyl acetate, 29 percent was exported, and 26 percent was used in the manufacture of cellulose acetate.

3.9 Major Buyers in Canada (Corpus 1983)

Allied Chemical, Montreal, Que.
Arliss Chemical, Montreal, Que.
C-I-L, Willowdale, Ont.

Canada Colors & Chemicals, Toronto, Ont.
Christie Chemical, Montreal, Que.
Harrison & Crosfield, Winnipeg, Man.
Shefford Chemicals, Granby, Que.
Signal Chemicals, Toronto, Ont.
Stanchem, Montreal, Que.
Uniroyal Chemical, Edmonton, Alta.
Van Waters & Rogers, Vancouver, B.C.

4 MATERIAL HANDLING AND COMPATIBILITY

4.1 Containers and Transportation Vessels

4.1.1 Bulk Shipment. Acetic acid in glacial and solution form is shipped bulk in specially designed railway tank cars and tank motor vehicles.

4.1.1.1 Railway tank cars. Railway tank cars used in the transportation of acetic acid are listed in Table 2. Glacial acetic acid is usually shipped in 111A60ALW1 railway tank cars as shown in Figure 7. Table 3 indicates railway tank car details associated with this drawing (TCM 1979; RTDCR 1974). The cars are unloaded from the top using compressed air or through the bottom using a pump. During top unloading, the acid is withdrawn through an eduction pipe which extends from the bottom of the tank to the top operating platform where it terminates with a 51 mm (2 in.) unloading connection valve. Air pressure of 103 kPa (15 psi) is applied through the 25 mm (1 in.) air connection valve (MCA 1951). Outside heating coils and fibreglass insulation may be required so that glacial acid will not freeze at common winter temperatures. It is important to note that aluminum cars are commonly used for glacial acetic acid and steel cars for solutions of 90 percent or less (Celanese MSDS 1978).

4.1.1.2 Tank motor vehicles. The capacities of tank trucks transporting acetic acid range from 14 900 L (3300 gal.) to 22 500 L (5000 gal.) (Celanese MSDS 1978). Similar to railway tank cars, these highway tankers are unloaded from the top, usually the standpipe being extended down over the back of the tank. Compressed air is used for unloading. The air inlet is usually a 25 mm (1 in.) diameter male threaded connection located at the top of the trailer through which air pressure not exceeding 103 kPa (15 psi) may be applied. Tanks are insulated and have outside heating coils (MCA 1951).

Tank motor vehicles are not specifically regulated under Transport Canada Specifications. Acetic acid solutions are not transported under pressure. Highway tankers must be pressure tested at 155 kPa (22 psi) minimum to allow for the compressed air pressure of 103 kPa (15 psi) used during top unloading. The maximum working pressure of the tanker is in effect 103 kPa (15 psi).

4.1.2 Packaging. In addition to bulk shipments, acetic acid is also transported in drums. Drums fabricated from a variety of construction materials are permitted. Table 4 lists drum types and descriptions for acetic acid (TDGC 1980). Glass carboys, boxed or in expanded polyethylene containers, are also used.

TABLE 2 RAILWAY TANK CAR SPECIFICATIONS

CTC/DOT* Specification Number	Description
111A60ALW1	Aluminum fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Bottom outlet or washout optional. Safety valve (242 kPa) (35 psi) or safety vent (414 kPa) (60 psi).
111A100W6	Alloy (stainless) steel fusion-welded tank without dome. Insulated or uninsulated. Gauging device. Top unloading arrangement required. Bottom outlet or washout prohibited. Test pressure 690 kPa (100 psi).
103ALW	Aluminum fusion-welded tank with dome. Uninsulated or insulated. 2% dome. Safety valve (242 kPa) (35 psi) or safety vent (414 kPa) (60 psi). Bottom outlet or washout optional.
103DW	Stainless steel fusion-welded tank with dome. Uninsulated or insulated. 2% dome. Safety valve (242 kPa) (35 psi) or safety vent (414 kPa) (60 psi).

* Canadian Transport Commission and Department of Transportation (U.S.)

4.2 Off-loading

4.2.1 Off-loading Equipment and Procedures for Railway Tank Cars. Prior to off-loading, certain precautions must be taken (MCA 1951):

- The vented storage tank must be checked to make sure that it will hold the contents of the car.
- Personnel must not enter the car under any circumstances.
- Brakes must be set, wheels chocked, derails placed and caution placards displayed.
- A safe operating platform must be provided at the unloading point.

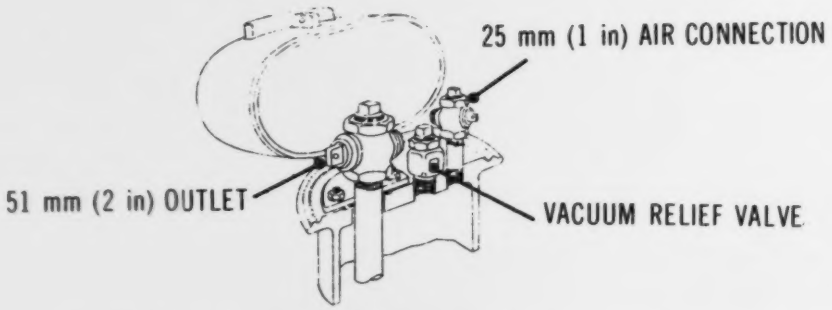
Proceed with off-loading by air pressure as follows (MCA 1951):

- In cold weather, connect the steam coil connection valves indicated in Figure 7 to live steam. Maximum pressure that may be applied is 1035 kPa (150 psi). Vents must be opened before heat is applied.

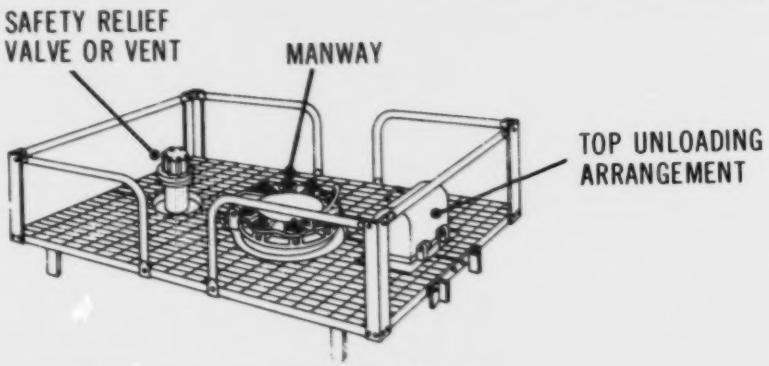
ACETIC ACID

RAILWAY TANK CAR - CLASS 111A60ALW1

(Reference - TCM 1979; RTDCR 1974)



Detail of top unloading arrangement



Detail of loading platform

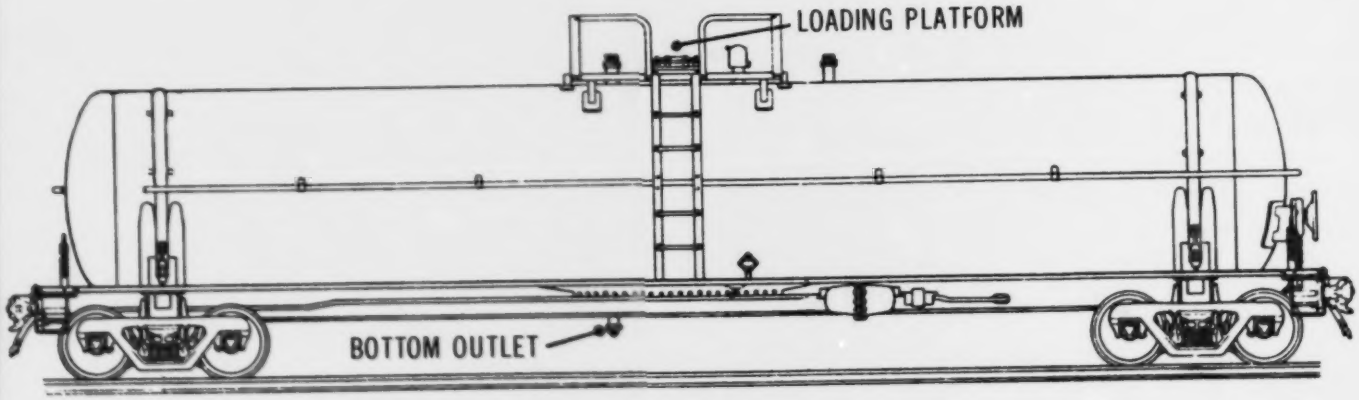


Illustration of tank car layout

TABLE 3 TYPICAL RAILWAY TANK CAR SPECIFICATIONS - CLASS 111A60ALW1 (TCM 1979; RTDCR 1974)

Description	Tank Car Size (Imp. Gal.) 16 700	17 200	20 000
Overall			
Nominal capacity	75 700 L (16 700 gal.)	78 000 L (17 200 gal.)	90 900 L (20 000 gal.)
Car weight - empty	33 900 kg (74 700 lb.)	33 900 kg (74 700 lb.)	38 900 kg (85 800 lb.)
Car weight - (max.)	119 000 kg (263 000 lb.)	83 500 kg (184 000 lb.)	119 000 kg (263 000 lb.)
Tank			
Material	Aluminum	Aluminum	Aluminum
Thickness	11.1 mm (7/16 in.)	11.1 mm (7/16 in.)	11.1 mm (7/16 in.)
Inside diameter	2.60 m (102 in.)	2.62 m (103 in.)	2.74 (108 in.)
Test pressure	414 kPa (60 psi)	414 kPa (60 psi)	414 kPa (60 psi)
Burst pressure	1640 kPa (240 psi)	1640 kPa (240 psi)	1640 kPa (240 psi)
Approximate Dimensions			
Coupled length	17 m (57 ft.)	17 m (57 ft.)	18 m (60 ft.)
Length over strikers	16 m (53 ft.)	16 m (53 ft.)	17 m (57 ft.)
Length of truck centres	13 m (42 ft.)	13 m (42 ft.)	14 m (45 ft.)
Height to top of grating	4 m (12 ft.)	4 m (12 ft.)	4 m (13 ft.)
Overall height	5 m (15 ft.)	5 m (15 ft.)	5 m (15 ft.)
Overall width (over grabs)	3.2 m (127 in.)	3.2 m (127 in.)	3.2 m (127 in.)
Length of grating	2-3 m (8-10 ft.)	2-3 m (8-10 ft.)	2-3 m (8-10 ft.)
Width of grating	1.5-2 m (5-6 ft.)	1.5-2 m (5-6 ft.)	1.5-2 m (5-6 ft.)
Loading/Unloading Fixtures			
Top Unloading			
Unloading connection	51 mm (2 in.)	51 mm (2 in.)	51 mm (2 in.)
Manway/fill hole	203-356 mm (8-14 in.)	203-356 mm (8-14 in.)	203-356 mm (8-14 in.)
Air connection	25-51 mm (1-2 in.)	25-51 mm (1-2 in.)	25-51 mm (1-2 in.)
Bottom Unloading			
Bottom outlet	102-152 mm (4-6 in.)	102-152 mm (4-6 in.)	102-152 mm (4-6 in.)
Safety Devices	Safety vent or valve	Safety vent or valve	Safety vent or valve
Dome	None	None	None
Insulation	Optional	Optional	Optional

TABLE 4 DRUMS

Type of Drum	Designation	Description	Figure No. (If Any)
Steel	1A1	Nonremovable head, reusable	8
	1A1A	1A1 with reinforced chime	8
	1A1B	1A1 with welded closure flange	8
	1A1C	1A1 with lead coating	8
	1A1D	1A1 with coating (other than lead)	8
	1A3	Nonremovable head, single use only	
Plastic	1H1	Nonremovable head. Maximum capacity 250 L (55 gal.). Maximum net mass 400 kg (880 lb.)	
Steel Drums with inner plastic receptacles	6HA1	Outer steel sheet in the shape of drum. Inner plastic receptacle. Maximum capacity of 225 L (50 gal.)	
Monel*	TC5M		8
Nickel	TC5K	Similar to monel drum, only nickel	

*See section 4.3 of this report.

- Connect the 51 mm (2 in.) unloading line to the discharge outlet and connect the 25 mm (1 in.) air line. Air pressure must be reduced to 103 kPa (15 psi) for unloading. A safety relief valve must be installed in the air line to release at 121 kPa (17.5 psi).
- After opening the air supply valve, the unloading connection valve can then be opened to unload the car.
- Once the car is empty, the air supply valve must be closed and the vent valve in the air line opened to allow the line pressure to equalize to atmospheric pressure.
- Reverse the above procedure to close up the car.

Proceed with bottom unloading as follows (MCA 1951):

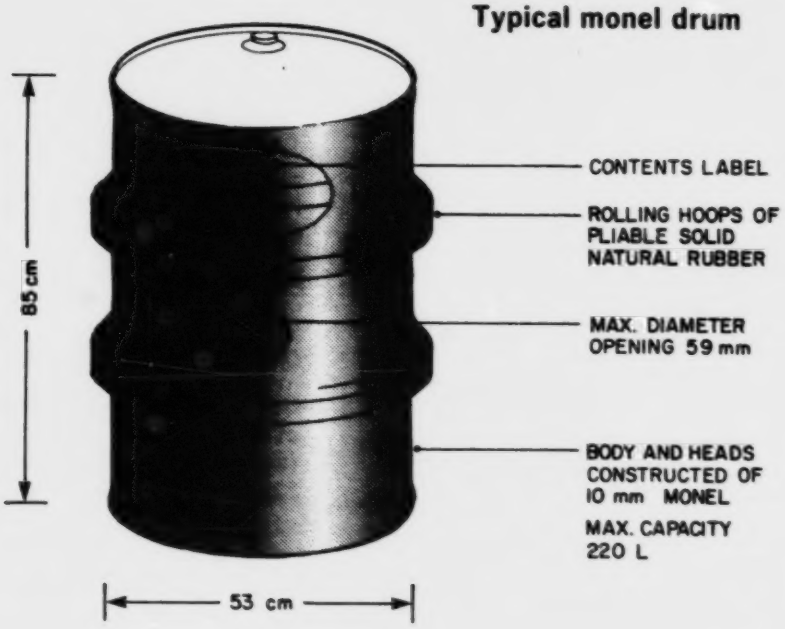
- Connect live steam to the bottom outlet connection as indicated in Figure 7.
- Make sure vents are functioning properly.
- Commence pumping to remove contents.

FIGURE 8

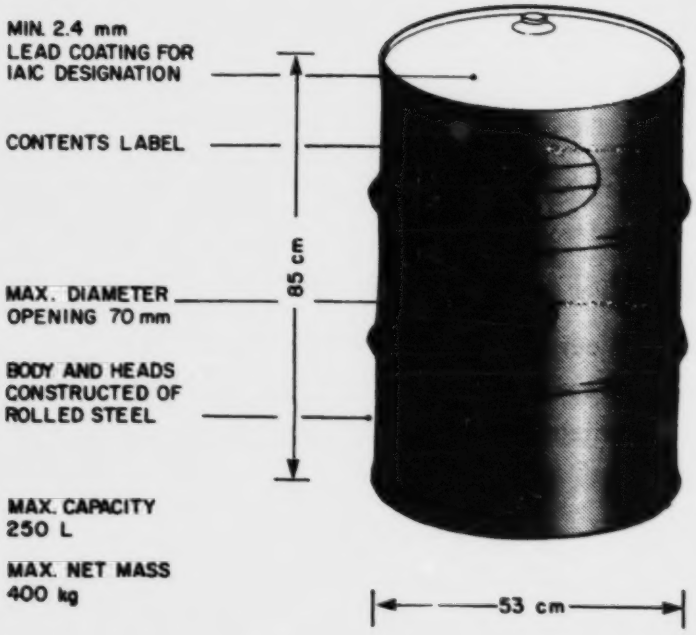
ACETIC ACID

TYPICAL DRUM CONTAINERS

Typical monel drum


85 cm
53 cm
CONTENTS LABEL
ROLLING HOOPS OF PLIABLE SOLID NATURAL RUBBER
MAX. DIAMETER OPENING 59 mm
BODY AND HEADS CONSTRUCTED OF 10 mm MONEL
MAX. CAPACITY 220 L

Typical steel drum


MIN. 2.4 mm LEAD COATING FOR IAIC DESIGNATION
CONTENTS LABEL
85 cm
MAX. DIAMETER OPENING 70 mm
BODY AND HEADS CONSTRUCTED OF ROLLED STEEL
MAX. CAPACITY 250 L
MAX. NET MASS 400 kg
53 cm

4.2.2 Off-loading Equipment and Procedures for Tank Motor Vehicles. The unloading of tank trailers is similar to that of railway tank cars. The general procedures for tank cars apply equally well to tank trailers.

4.2.3 Specifications and Materials for Off-loading Equipment. The materials of construction for off-loading system components discussed in this section along with specifications refer to those generally used. It is recognized that other materials may be used for particular applications as indicated in Table 5.

Schedule 40 aluminum or schedule 40 stainless steel 316 pipes and welding fittings are recommended for glacial acetic acid. Aluminum is not recommended for dilute solutions. Flanged joints should be used and these should be welded, because threaded pipes and fittings tend to leak (MCA 1951). The unloading line should be 51 mm (2 in.) pipe because this is the standard fitting on tank cars; however, process pipe may be almost any size. Pipe under 25 mm (1 in.), however, is not recommended. Outdoor lines must be self-draining and may be insulated depending upon acid strength. These can be steam traced with 9 or 13 mm (3/8 or 1/2 in.) copper tubing or steel pipe located inside the insulation (MCA 1951).

Stainless steel pipe and swivel joints may be used for flexible sections at rail car or tank truck unloading stations. Either the ball bearing type swivel joint or the simple stuffing box type will give adequate service with proper maintenance.

Cast iron or cast steel diaphragm valves lined with polyvinylidene chloride resin will serve adequately (DPLV 1972). Refer to Table 5 for other material possibilities.

A single-suction centrifugal pump with wet end material of SS 316 and high silicon cast iron casing is recommended for pumping (MCA 1951). Teflon is a good packing material.

Storage tanks, especially if located outside, should be insulated and equipped with steam coils to keep the acid from freezing (MCA 1951).

4.3 Compatibility with Materials of Construction

The compatibility of acetic acid with materials of construction is indicated in Table 5. The unbracketed abbreviations are described in Table 6. The rating system for this report is briefly described below.

Recommended: This material will perform satisfactorily in the given application.

Conditional: Material will show deterioration in the given application; however, it may be suitable for intermittent or short-term service.

Not Recommended: Material will be severely affected in this application and should not be used.

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

	Chemical		Material of Construction		
Application	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
1. Pipes and Fittings	10%	66	PVDC (DCRG 1978)		
		93	PP (DCRG 1978)		
		107	PVDF (DCRG 1978)		
		121	Chlorinated Polyether (DCRG 1978)		
	To 20%	23			ABS (DPPED 1967)
		24	ABS* (MWPP 1978)		
		49	PE (DPPED 1967)		
		60	PVC I PVC II (DPPED 1967)		
		To operating limit of material	PVC I PE (MWPP 1978)		
	Glacial				PE (MWPP 1978)
		23		PVC I (DPPED 1967)	PCV II (DPPED 1967)
		24	PVC I* (MWPP 1978)		
		49			PVC I (DPPED 1967

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (Cont'd)

Application	Chemical		Material of Construction		
	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
1. Pipes and Fittings (Cont'd)	Glacial	52	PVDC (DCRG 1978)		
		66	PVDF (DCRG 1978)		
		93	PP (DCRG 1978)		
		121	Chlorinated Polyether (DCRG 1978)		
2. Valves	All, Glacial	21	SS J-20 SS 316 (JSSV 1979)		
	Glacial	Boiling	SS J-20 SS 316 (JSSV 1979)		
3. Pumps	10%	82	GRP with PTFE "0" Ring		
	Glacial				
	Dilute	Cold	All Iron SS 304, SS 316, High Silicon, Cast Iron (HIS 1969)		
	Conc.	Boiling	SS 316 High Silicon Cast Iron (HIS 1969)		
4. Storage	<90%	Most	Aluminum		
	All	Most	SS 316, SS 317 SS 318, CS Glass-lined (MCA 1951)		
5. Others	5-10%	20	SS 302, SS 304, SS 316, SS 410, SS 430 (ASS)		
	10%	22	CPVC (TPS 1978)		

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (Cont'd)

Application	Chemical		Material of Construction		
	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
5. Others (Cont'd)	10%	60	PVC (TPS 1978)		
		82	PP (TPS 1978)		
		85		CPVC (TPS 1978)	
	Up to 25%	40	uPVC, PE, NR*, IIR*, EPDM, CSM* (GF)	POM, CR* (GF)	NBR, FPM (GF)
	Dilute		Si (GPP)		SBR, NR, CR, IIR, CSM (GPP)
	Glacial	20	SS 302, SS 304, SS 316 (ASS) PE, PP, IIR, EPDM (GF)	uPVC, NR*, CR* (GF)	SS 410 (ASS) POM, NBR, FPM, CSM (GF)
		22			PVC, CPVC (TPS 1978)
		49	PP (TPS 1978)		
		66	PVDF (TPS 1978)	PP (TPS 1978)	
		60	IIR*, EPDM (GF)	PE, PP, NR (GF)	uPVC, POM, NBR, CR, FPM, CSM (GF)
		Boiling			SS 302, SS 304, SS 316, SS 430 (ASS)
		121			PVDF (TPS 1978)
			EPDM (GPP)		NR, SBR, CR, NBR, IIR, CSM (GPP)

* This material has been given a lower rating in a similar application by another reference.

TABLE 6 MATERIALS OF CONSTRUCTION

Abbreviation	Material of Construction
ABS	Acrylonitrile Butadiene Styrene
	Aluminum
	Cast Iron, Austenitic
	Cast Iron, High Silicon
	Chlorinated Polyether
CPVC	Chlorinated Polyvinyl Chloride
CR	Polychloroprene (Neoprene) Rubber
CS	Carbon Steel
CSM	Chlorosulphonated Polyethylene (Hypalon)
EPDM	Ethylene Propylene Rubber
FPM	Fluorine Rubber (Viton)
	Glass
	Glass Reinforced Vinyl Ester
	Iron
IIR	Isobutylene/Isoprene (Butyl) Rubber
NBR	Acrylonitrile/Butadiene (Nitrile, Buna N) Rubber
NR	Natural Rubber
	Nickel
	Nickel-Copper Alloy (Monel)
PE	Polyethylene
POM	Polyoxymethylene
PP	Polypropylene
PTFE	Polytetrafluoroethylene (Teflon)
PVC (Followed by grade, if any)	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride (Saran)
PVDF	Polyvinylidene Fluoride
SBR	Styrene/Butadiene (GR-5, Buna S) Rubber
Si	Silicon
SS (Followed by grade)	Stainless Steel
	"20" Alloy (Durimet 20, Carpenter 20)
uPVC	Unplasticized Polyvinyl Chloride

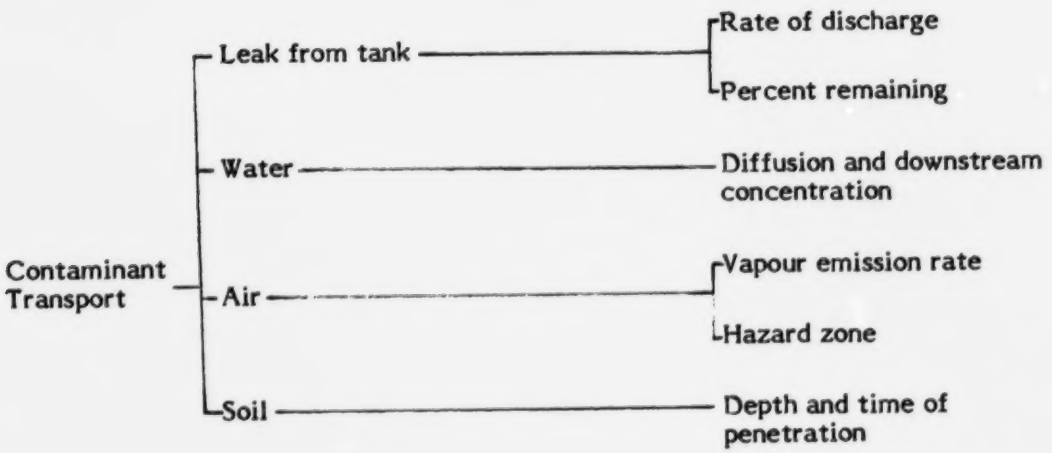
5 CONTAMINANT TRANSPORT

5.1 General Summary

Acetic acid is transported in glacial or solution forms. When spilled in water, all forms will mix rapidly; the heat of reaction may produce significant amounts of vapour. When spilled on soil, the liquid will spread on the surface and penetrate into the soil at a rate dependent on the soil type and its water content. Downward transport of the liquid toward the groundwater table may be an environmental problem.

Acetic acid is a liquid with a relatively low volatility; however, the vapour released from a liquid pool on the ground surface may be a potential environmental hazard.

The following factors are considered for the transport of a spill in water and soil:



It is important to note that, because of the approximate nature of the contaminant transport calculations, the approach adopted throughout has been to use conservative estimates of critical parameters so that predictions are approaching worst case scenarios for each medium. This may require that the assumptions made for each medium be quite different and to some extent inconsistent. As well as producing worst case scenarios, this approach allows comparison of the behaviours of different chemicals under consistent assumptions.

5.2 Leak Nomograms

5.2.1 Introduction. Acetic acid is commonly transported in specially designed railway tank cars as a nonpressurized liquid. While the capacities of the tank cars vary

widely, one tank car size has been chosen throughout the EnviroTIPS series for development of the leak nomograms. It is approximately 2.75 m in diameter and 13.4 m long, with a carrying capacity of about 80 000 L.

If a tank car loaded with acetic acid is punctured on the bottom, all of the contents will drain out by gravity. The aim of the nomograms is to provide a simple means to obtain the time history of the conditions in the tank car and the venting rate of the liquid. Because of the relatively low volatility of acetic acid and the fact that the tank cars are not pressurized, no leak nomograms have been prepared for vapour release from a puncture in the top of the tank.

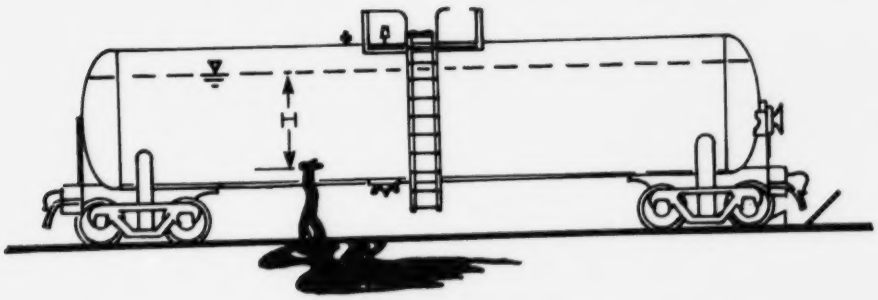


FIGURE 9 TANK CAR WITH PUNCTURE HOLE IN BOTTOM

5.2.2 Nomograms.

5.2.2.1 Figure 10: Percent remaining versus time. Figure 10 provides a means of estimating the percent of liquid remaining in the standard tank car after the time of puncture for a number of different hole diameters. The hole diameter is actually an equivalent diameter and can be applied to a noncircular puncture.

The standard tank car (2.75 m Ø x 13.4 m long) is assumed to be initially full (at t=0) with a volume of about 80 000 L of acetic acid. The amount remaining at any time (t) is not only a function of the discharge rate over time, but also of the size and shape of the tank car.

5.2.2.2 Figure 11: Discharge rate versus time. Figure 11 provides a means of estimating the instantaneous discharge rate (L/s) at any time (t) after the time of puncture for a number of equivalent hole diameters. The nomogram is only applicable to the standard tank car size with an initial volume of 80 000 L.

FIGURE 10

ACETIC ACID

PERCENT REMAINING VS TIME

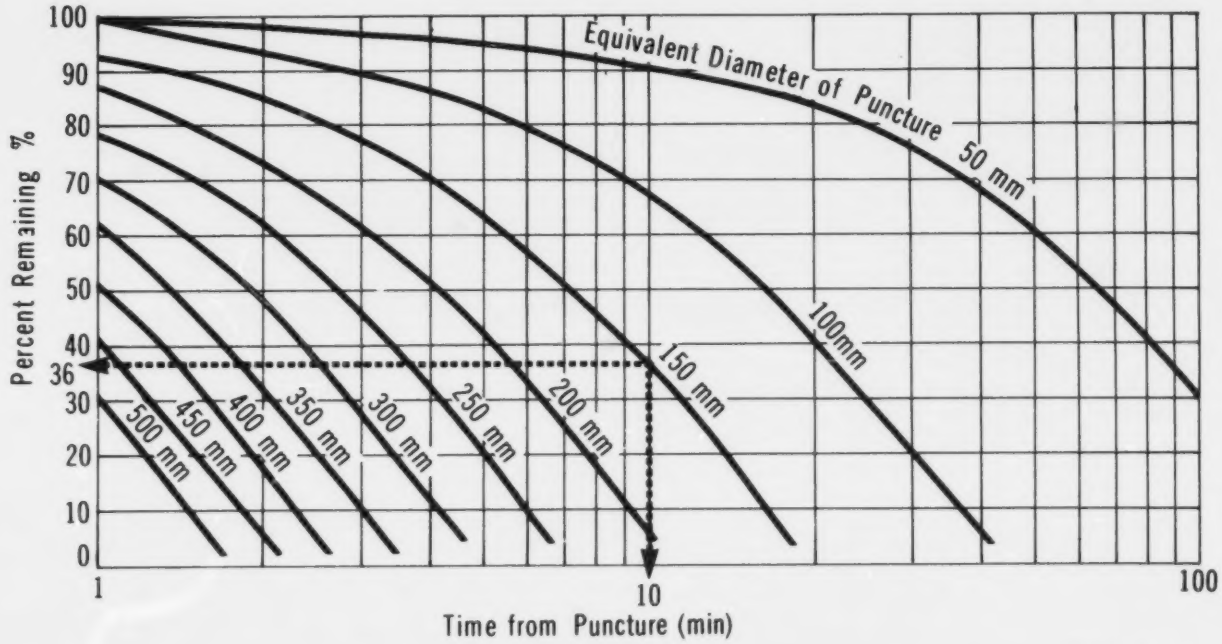
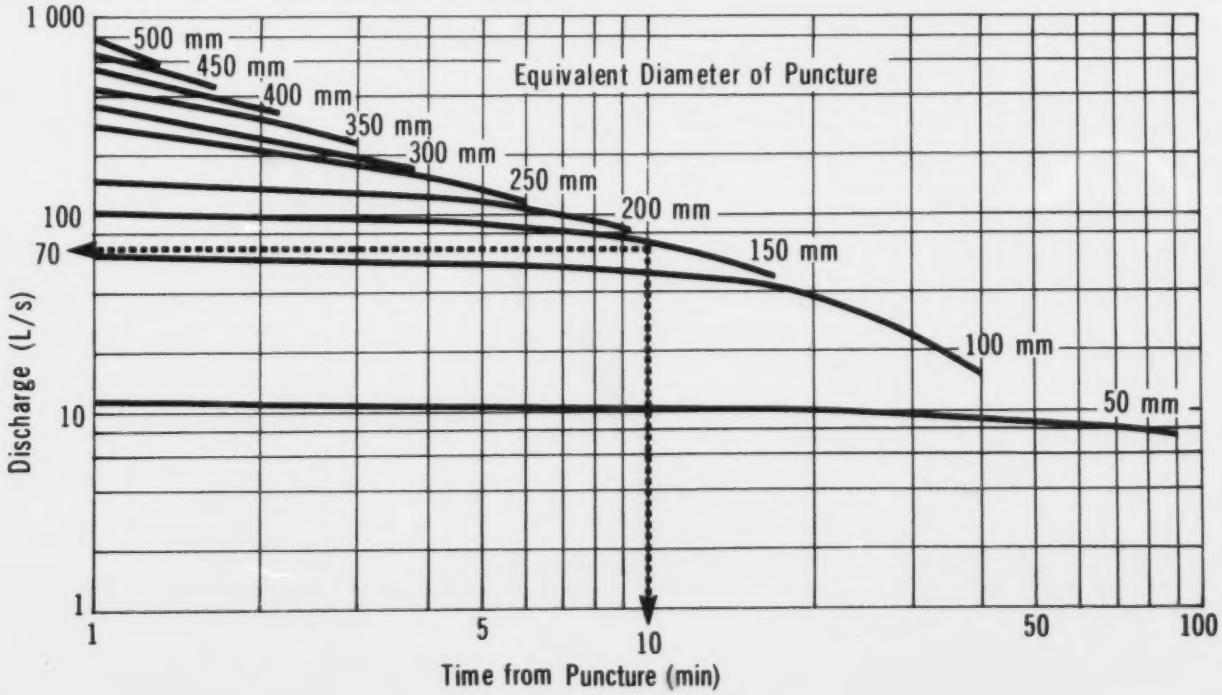


FIGURE 11

ACETIC ACID

DISCHARGE RATE VS TIME



5.2.3 Sample Calculations.

i) Problem A

The standard tank car filled with acetic acid has been punctured on the bottom. The equivalent diameter of the hole is 150 mm. What percent of the initial 80 000 L remains after 10 minutes?

Solution

- Use Figure 10
- With t=10 min and d=150 mm, the amount remaining is about 36 percent or 28 800 L

ii) Problem B

With the same conditions as Problem A, what is the instantaneous discharge rate from the tank 10 minutes after the accident?

Solution to Problem B

- Use Figure 11
- With t=10 min and d=150 mm, the instantaneous discharge rate (q) = 70 L/s

5.3 Dispersion in the Air

5.3.1 Introduction. Since acetic acid is a relatively nonvolatile liquid, direct venting of the vapour to the atmosphere from a hole in a punctured vessel does not constitute a significant hazard downwind. Only vapour released from a liquid pool spilled on a ground or water surface is treated here.

To estimate the vapour concentrations downwind of the accident site for the determination of the flammability or toxicity hazard zone, the atmospheric transport and dispersion of the contaminant vapour must be modelled. The models used here are based on Gaussian formulations and are the ones most widely used in practice for contaminant concentration predictions. The model details are contained in the Introduction Manual.

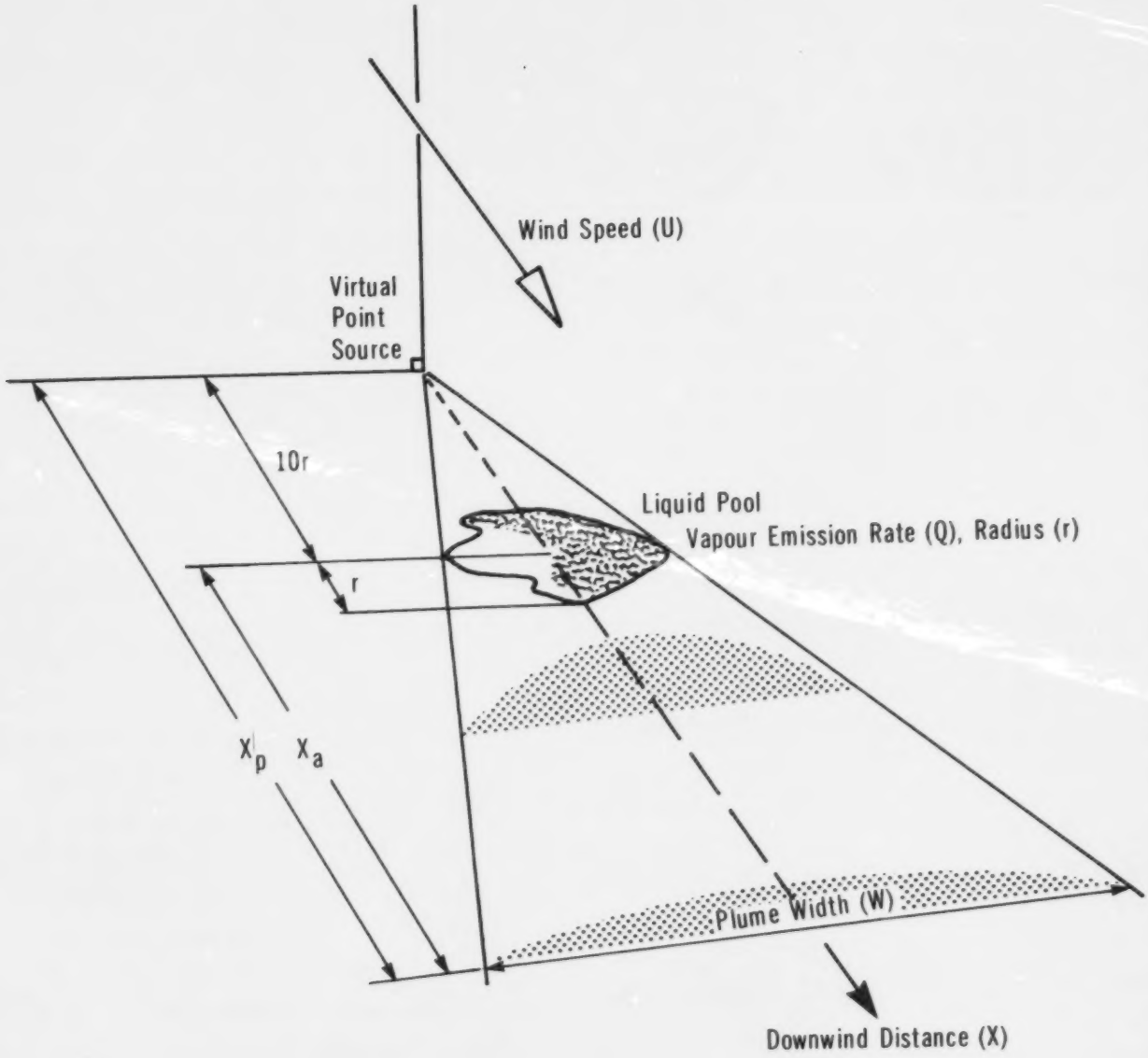
Figure 12 depicts schematically the contaminant plume configuration from a continuous surface release. The dispersion model represents the liquid pool area source as a virtual point source (with the same vapour emission rate, Q) located 12 equivalent pool radii upwind.

5.3.2 Vapour Dispersion Nomograms and Tables. The aim of the air dispersion nomograms is to define the hazard zone due to toxicity or flammability of a vapour cloud.

FIGURE 12

ACETIC ACID

SCHEMATIC OF CONTAMINANT PLUME



The following nomograms and data tables are contained in this section (to be used in the order given):

Figure 14:	vapour emission rate from a liquid pool as a function of maximum pool radius
Table 7:	weather conditions
Figure 15:	normalized vapour concentration as a function of downwind distance and weather conditions
Table 8:	maximum plume hazard half-widths
Figure 18:	vapour plume travel distance as a function of time elapsed since the spill and wind speed

The flowchart given in Figure 13 outlines the steps necessary to make vapour dispersion calculations and identifies the nomograms or tables to be used. This section deals only with the portion contained within the dashed box. Data on "total liquid discharged" is contained in Section 5.2. A description of each vapour dispersion nomogram and its use follows.

5.3.2.1 Figure 14: Vapour emission rate versus liquid pool radius for various temperatures. An evaporation rate for acetic acid (as glacial) has been calculated employing the evaporation rate equations contained in the Introduction Manual. The computed evaporation rate for glacial acetic acid at 20°C and a wind speed of 4.5 m/s (16.1 km/h) is 0.24 g/(m^2s). Evaporation rates at other temperatures have been calculated using the evaporation rate equation which, at given wind speed, is dependent on ambient temperature and the vapour pressure (Perry 1973) of acetic acid at that temperature. For example, evaporation rates of 0.077 g/(m^2s) at 0°C and 0.42 g/(m^2s) at 30°C were calculated for a wind speed of 4.5 m/s.

Use: For a pool of acetic acid of known radius, the rate (Q) at which acetic acid vapour is released to the atmosphere at a given temperature can then be estimated from Figure 14. The solid portions of the curves represent spills of 0.05 to 84 tonnes, the latter representing about one standard 80 000 L rail car load of acetic acid. It should be noted that Figure 14 is valid for a wind speed of 4.5 m/s (16.1 km/h) and therefore can only be used to provide an approximation of acetic acid vapour emission rates at other wind speeds. The Introduction Manual contains the appropriate equation to convert the evaporation rate at 4.5 m/s to an evaporation rate at another wind speed should it be desired.

It should also be noted that the determination of the emission rate is based on the spill radius on calm water (Table T1, CHRIS 1974). The spill radius employed was

FIGURE 13

ACETIC ACID

FLOW CHART TO DETERMINE VAPOUR HAZARD ZONE

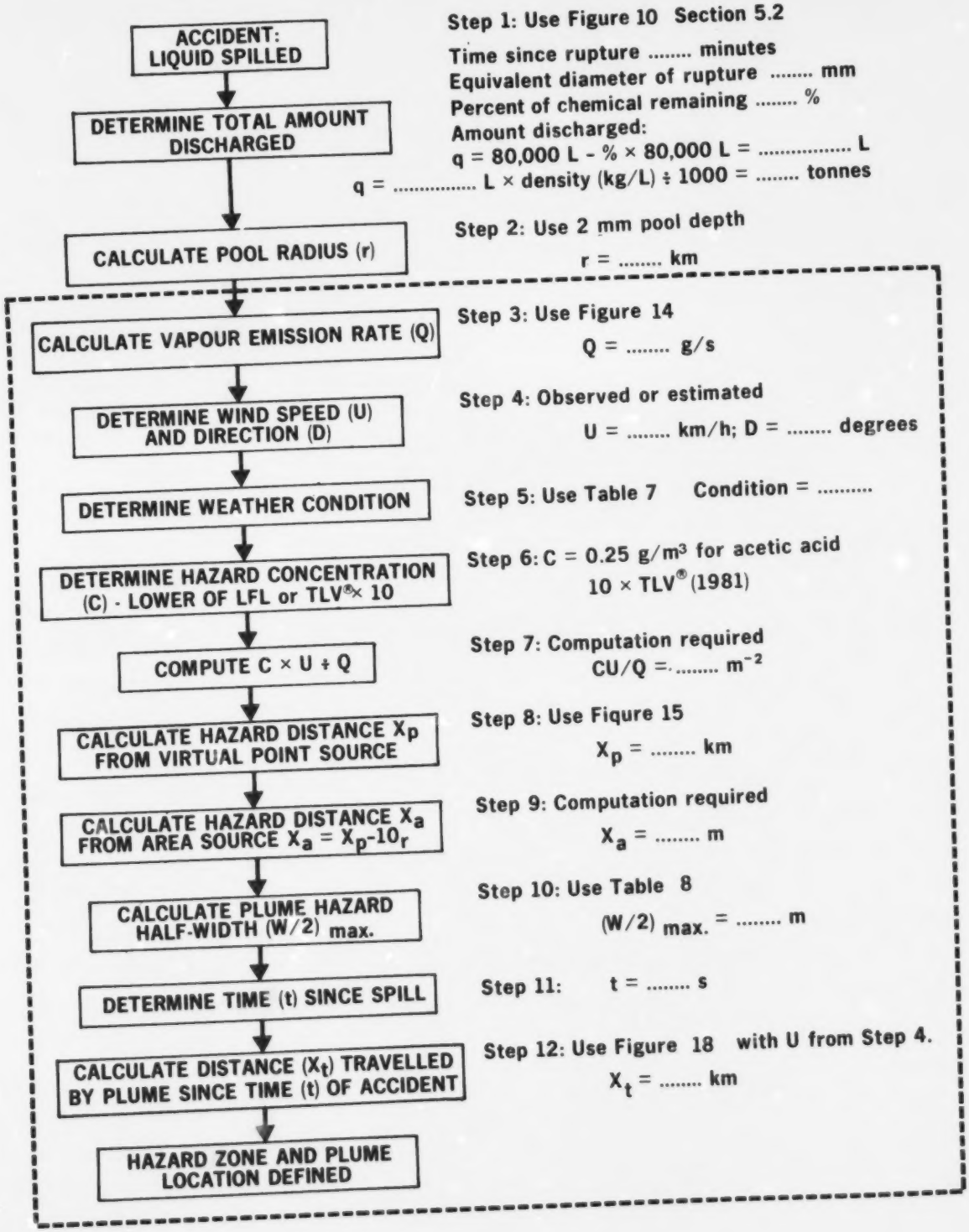
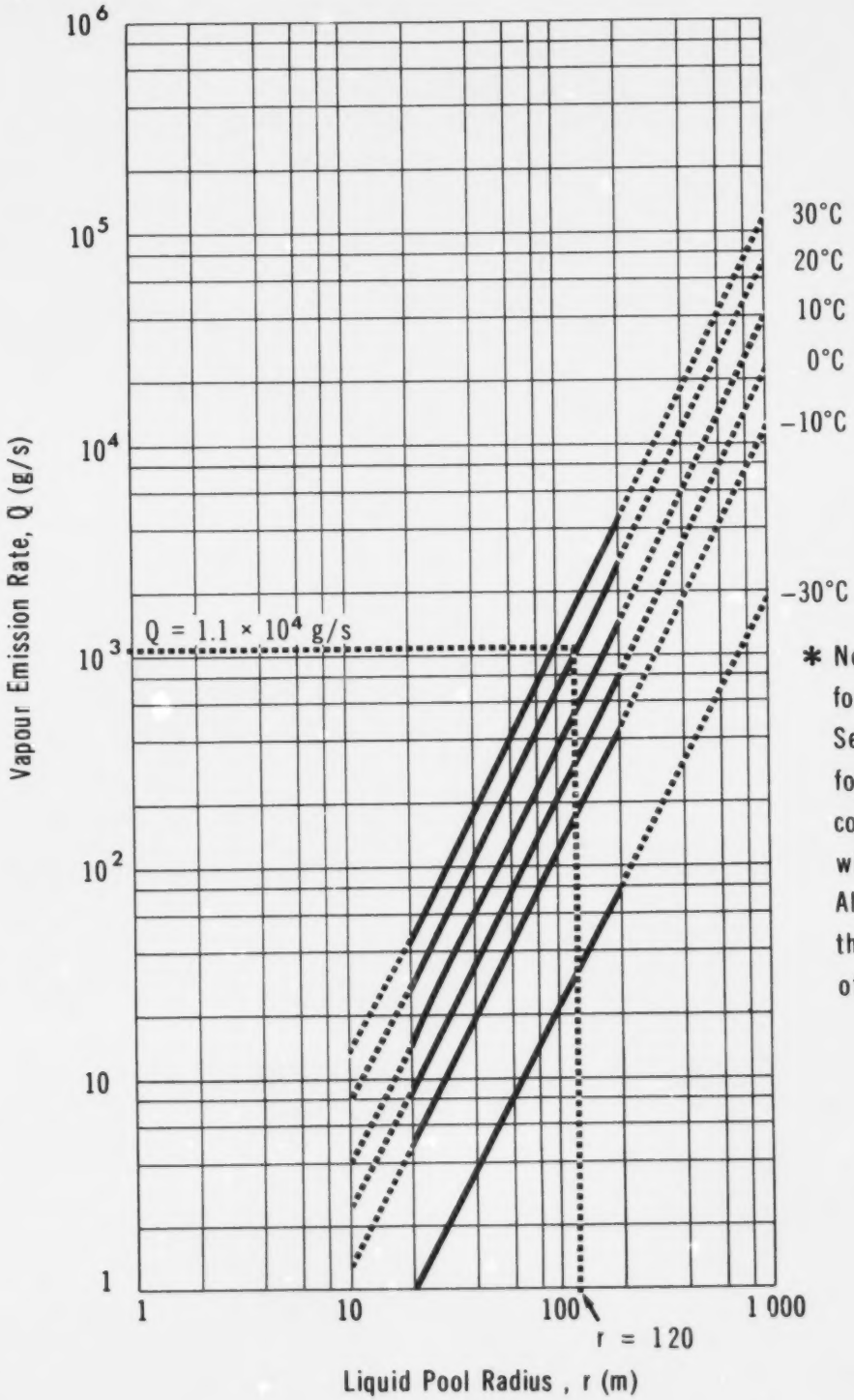

ACCIDENT: LIQUID SPILLED
DETERMINE TOTAL AMOUNT DISCHARGED
CALCULATE POOL RADIUS (r)
CALCULATE VAPOUR EMISSION RATE (Q)
DETERMINE WIND SPEED (U) AND DIRECTION (D)
DETERMINE WEATHER CONDITION
DETERMINE HAZARD CONCENTRATION (C) - LOWER OF LFL or TLV® × 10
COMPUTE C × U ÷ Q
CALCULATE HAZARD DISTANCE Xp FROM VIRTUAL POINT SOURCE
CALCULATE HAZARD DISTANCE Xa FROM AREA SOURCE Xa = Xp-10r
CALCULATE PLUME HAZARD HALF-WIDTH (W/2) max.
DETERMINE TIME (t) SINCE SPILL
CALCULATE DISTANCE (Xt) TRAVELLED BY PLUME SINCE TIME (t) OF ACCIDENT
HAZARD ZONE AND PLUME LOCATION DEFINED
Step 1: Use Figure 10 Section 5.2
Time since rupture ..... minutes
Equivalent diameter of rupture ..... mm
Percent of chemical remaining ..... %
Amount discharged:
q = 80,000 L - % × 80,000 L = ... L
q = ... L × density (kg/L) ÷ 1000 = ... tonnes
Step 2: Use 2 mm pool depth
r = ... km
Step 3: Use Figure 14
Q = ... g/s
Step 4: Observed or estimated
U = ... km/h; D = ... degrees
Step 5: Use Table 7 Condition = ...
Step 6: C = 0.25 g/m3 for acetic acid
10 × TLV® (1981)
Step 7: Computation required
CU/Q = ... m-2
Step 8: Use Fiqure 15
Xp = ... km
Step 9: Computation required
Xa = ... m
Step 10: Use Table 8
(W/2) max. = ... m
Step 11: t = ... s
Step 12: Use Figure 18 with U from Step 4.
Xt = ... km

FIGURE 14

ACETIC ACID

VAPOUR EMISSION RATE VS LIQUID POOL RADIUS FOR VARIOUS TEMPERATURES



* Note: Nomogram applies for wind speed of 4.5 m/s. See Introduction Manual for relationships to compute values for other wind speeds, if necessary. Also, the solid portions of the curves represent spills of 0.05 to 84 tonnes.

arbitrarily chosen as an intermediate value between that of benzene (a moderately volatile liquid) and that of iso-amyl nitrite (a nonvolatile liquid). This model situation was chosen to apply for water-soluble liquids with boiling points above ambient temperature, and to a limited number of water-soluble and water-insoluble organic liquids that are not treated by CHRIS (CHRIS 1974). Since calm water represents a flat, unbounded surface compared to the type of ground surface that would normally be encountered in a spill situation (namely, irregular and porous), the spill radius on calm water is considered to provide the maximum value. Therefore, when spills on land are assessed by using the water algorithm, the spill radius would be overestimated and worst case values are provided.

5.3.2.2 Figure 15: Normalized vapour concentration versus downwind distance. Figure 15 shows the relationship between the vapour concentration and the downwind distance for weather conditions D and F. The nomograms were developed using the dispersion models described in the Introduction Manual. The vapour concentration is represented by the normalized, ground-level concentration (CU/Q) at the centreline of the contaminant plume. Weather condition F is the poorest for dispersing a vapour cloud and condition D is the most common in most parts of Canada. Before using Figure 15, the weather condition must be determined from Table 7.

TABLE 7 WEATHER CONDITIONS

Weather Condition F	Weather Condition D
Wind speed <11 km/h (≈3 m/s) and one of the following:	All other weather conditions
- overcast day	
- night time	
- severe temperature inversion	

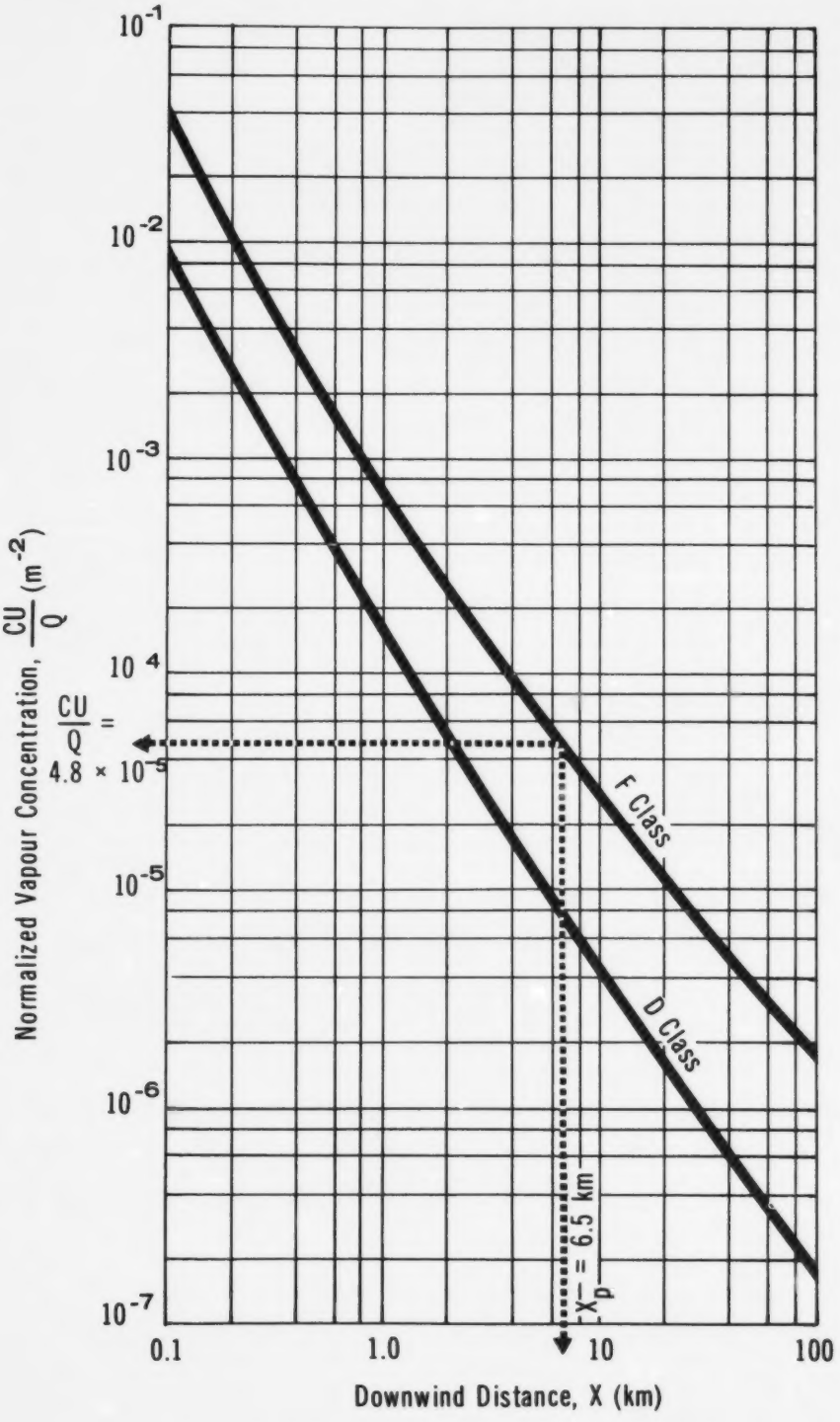
Use: The maximum hazard distance, X_p, downwind of the spill can be calculated from Figure 15 knowing:

- Q, the vapour emission rate (g/s)
- U, the wind speed (m/s)
- the weather condition

FIGURE 15

ACETIC ACID

NORMALIZED VAPOUR CONCENTRATION VS DOWNWIND DISTANCE



the hazard concentration limit, C, which is the lower value of 10 times the Threshold Limit Value (TLV•, in g/m^3), or the Lower Flammability Limit (LFL, in g/m^3). Note: To convert the TLV• (in ppm) and the LFL (in percent by volume) to concentrations in g/m^3, use Figures 16 and 17

A hazard concentration limit of 10 times the TLV• has been arbitrarily chosen as it represents a more realistic level at which there would be concern for human health on the short term (i.e., on the order of 30 minutes). The TLV• is a workplace standard for long-term exposure and use of this value as the hazard limit would result in unrealistically large hazard zones.

5.3.2.3 Table 8: Maximum plume hazard half-widths. This table presents data on the maximum plume hazard half-width, $(W/2)_{max}$, for a range of Q/U values under weather conditions D and F. These data were computed using the dispersion modelling techniques given in the Introduction Manual for a value of 10 times the acetic acid Threshold Limit Value (TLV•) of 0.025 g/m^3, or 0.25 g/m^3. The maximum plume hazard half-width represents the maximum half-width of the acetic acid vapour cloud, downwind of the spill site, corresponding to a hazard concentration limit of 10 x TLV•. Table 8 is therefore only applicable for an acetic acid hazard concentration limit of 10 x TLV• or 0.25 g/m^3. Also, data are provided up to a maximum hazard distance downwind of 100 km.

Under weather condition D, the wind speed (U) range applicable is 1 to 30 m/s. The range of vapour emission rates (Q) used was 3000 to 1 600 000 g/s, corresponding to acetic acid spills in the range of about 3 to greater than 8000 tonnes, respectively. If the entire contents of an 80 000 L (17 600 Imp. gal.) tank car spill, the mass spilled would be 84 000 kg or approximately 84 tonnes. Therefore, under Class D of Table 8, data are provided for up to greater than 95 times this amount.

Under weather condition F, the wind speed (U) range applicable is 1 to 3 m/s. The range of vapour emission rates (Q) used was 300 to 165 000 g/s, corresponding to acetic acid spills in the range of about 0.05 to 1500 tonnes, respectively. Therefore, under class F of Table 8, data are provided for up to 17 times a standard rail car load.

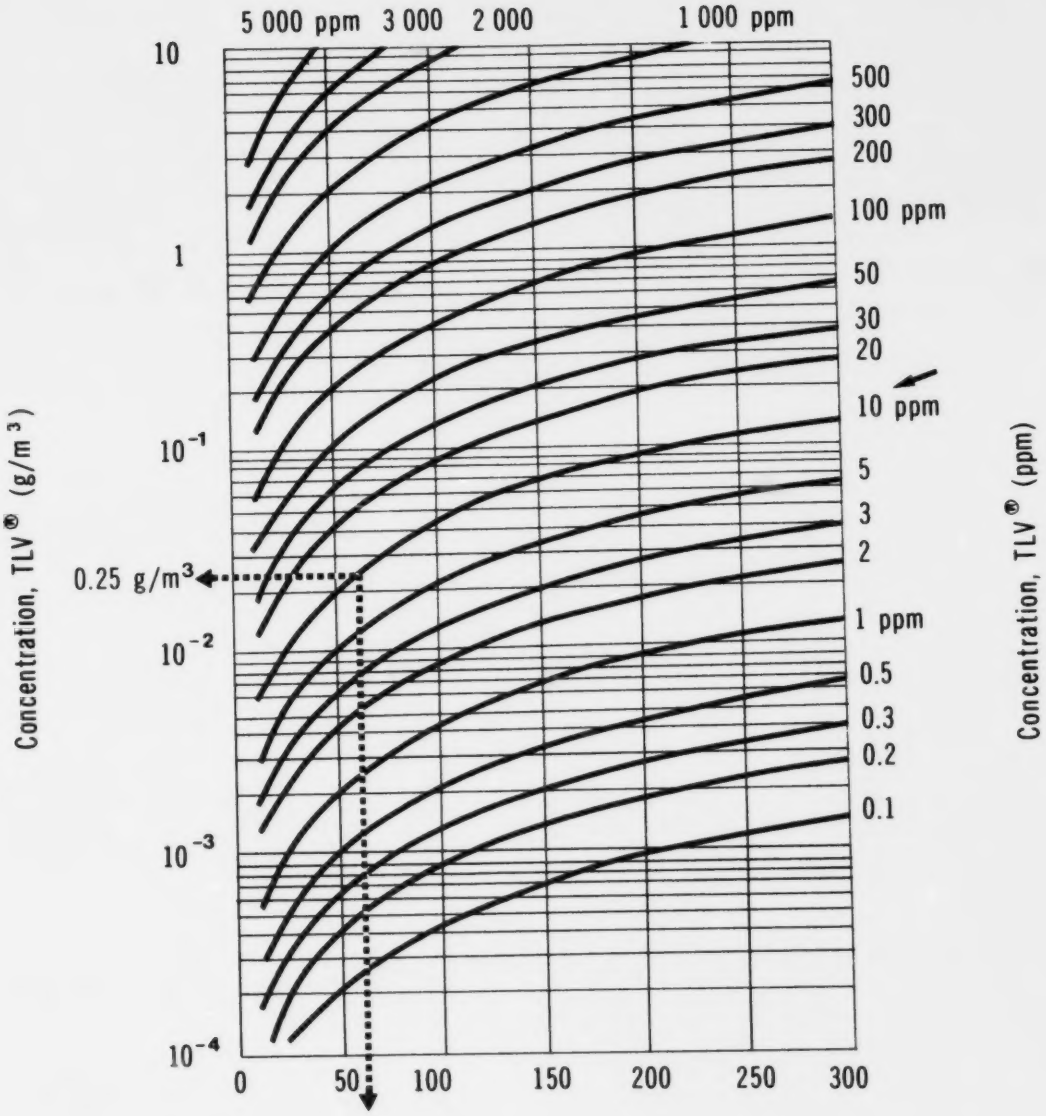
Use: Knowing the weather condition, Q and U, compute Q/U. Choose the closest Q/U value in the table and the corresponding $(W/2)_{max}$, the maximum plume hazard half-width, in metres. (For an intermediate value, interpolate Q/U and $(W/2)_{max}$ values.) Also refer to the example at the bottom of Table 8.

5.3.2.4 Figure 18: Plume travel time versus travel distance. Figure 18 presents plots of plume travel time (t) versus plume travel distance (X_t) as a function of different wind

FIGURE 16

ACETIC ACID

CONVERSION OF THRESHOLD LIMIT VALUE (TLV®) UNITS (ppm to g/m³)



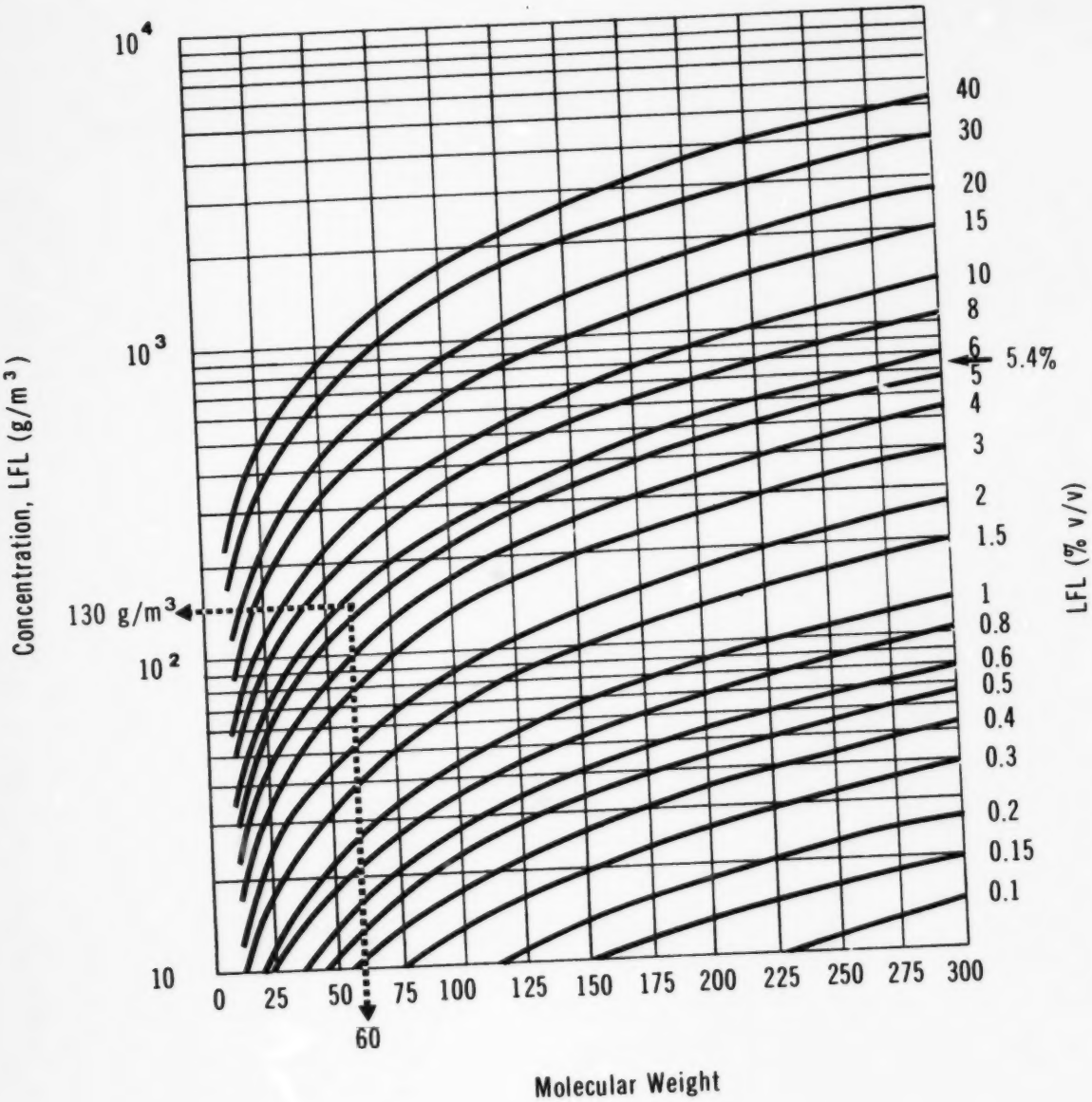
Example: Acetic acid MW = 60, TLV® = 10 ppm,
then TLV® in g/m³ = 0.25

Note: data applicable at 25°C and 760 mm Hg pressure

FIGURE 17

ACETIC ACID

CONVERSION OF LOWER FLAMMABILITY LIMIT (LFL) UNITS (volume % to g/m³)



Example: Acetic acid, MW = 60, LFL = 5.4%, then LFL in g/m³ = 130

Note: data applicable at 25°C and 760 mm Hg pressure

TABLE 8 MAXIMUM PLUME HAZARD HALF-WIDTHS (FOR ACETIC ACID AT 20°C)

Weather Condition D			Weather Condition F		
Q/U (g/m)	$(W/2)_{max}$ (m)		Q/U (g/m)	$(W/2)_{max}$ (m)	
1 600 000	3245	(99.5 km)*	165 000	1540	(99.5 km)*
1 400 000	2985		150 000	1430	
1 200 000	2715		125 000	1250	
1 000 000	2425		100 000	1060	
800 000	2110		75 000	855	
600 000	1770		50 000	630	
500 000	1580		40 000	535	
400 000	1375		30 000	430	
300 000	1150		25 000	375	
200 000	895		20 000	325	
150 000	750		15 000	270	
125 000	670		10 000	210	
100 000	585	Q/U = 5240 →	5 000	135 →	$(W/2)_{max}$ = 140 m
75 000	500		2 000	75	
50 000	395		1 000	50	
25 000	260		500	35	
20 000	230		200	20	
15 000	195		100	15	
10 000	155				
5 000	100				
2 000	60				
1 000	40				
500	30				
200	20				
100	15				

* Data are provided up to a maximum downwind hazard distance of 100 km

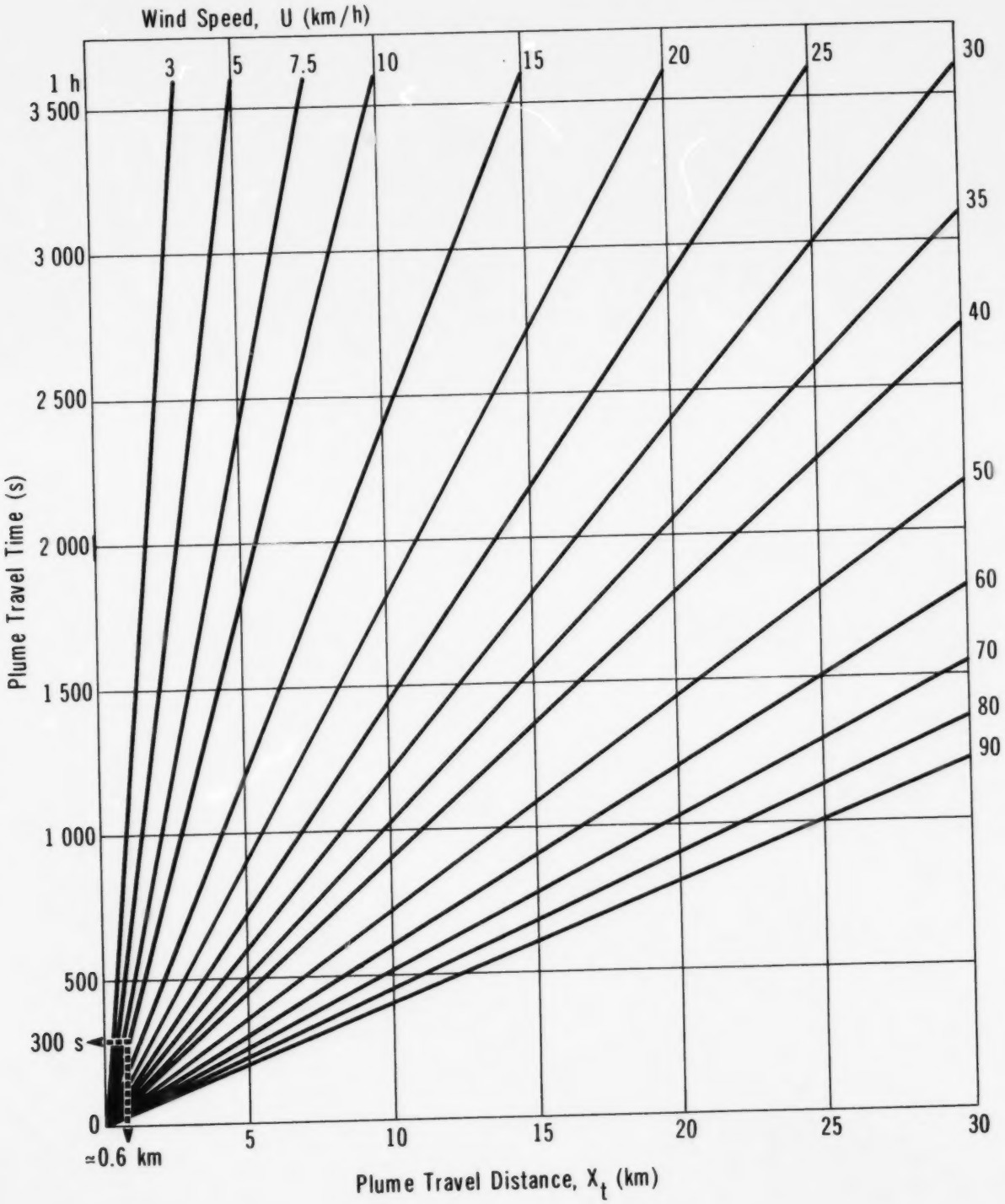
Example: A spill releasing acetic acid vapour at the rate of Q = 1.1 x 10^4 g/s under weather condition F and a wind speed U = 2.1 m/s means Q/U = 5240 g/m which results in a maximum plume hazard half-width $(W/2)_{max}$ = 140 m.

Note: Above table is valid only for an acetic acid concentration of 10 x TLV•, or 0.25 g/m^3.

FIGURE 18

ACETIC ACID

PLUME TRAVEL TIME VS TRAVEL DISTANCE



speeds (U). This is simply the graphical presentation of the relationship $X_t = Ut$ for a range of typical wind speeds.

Use: Knowing the time (t) since the spill occurred and the wind speed (U), the distance (X_t) can be determined which indicates how far downwind the plume has travelled.

5.3.3 Sample Calculation. The sample calculation given below is intended to outline the steps required to estimate the downwind hazard zone which could result from a spill of liquid acetic acid. The user is cautioned to take note of the limitations in the calculation procedures described herein and in the Introduction Manual. The estimates provided here apply only for conditions given. It is recommended that the user employ known or observational estimates (i.e., of the spill radius) in a particular spill situation if possible.

Problem:

During the night, at about 2:00 a.m., 20 tonnes of acetic acid were spilled on a flat ground surface. It is now 2:05 a.m. The temperature is 20°C and the wind is from the NW at 7.5 km/h. Determine the extent of the vapour hazard zone.

Solution

Step 1: Quantity spilled is given, q = 20 tonnes

Step 2: Determine the pool radius (r) for a spill of 20 tonnes

- Use observed (measured) pool radius if possible. If not, use the maximum radius calculated assuming a 2 mm spill thickness
- Radius (r) = 120 m ÷ 1000 = 0.12 km

Step 3: Calculate the vapour emission rate (Q) at T = 20°C

- From Figure 14, for r = 120 m and T = 20°C, $Q = 1.1 \times 10^4$ g/s

Step 4: Determine the wind speed (U) and direction (D)

- Use available weather information, preferably on-site observations
- Given:

  U = 7.5 km/h, then U = 7.5 ÷ 3.6 = 2.1 m/s

  D = NW or 315° (D = Direction from which wind is blowing)

Step 5: Determine the weather condition

- From Table 7, weather condition = F since U is less than 11 km/h and it is night

Step 6: Determine the hazard concentration limit (C)

- This is the lower of 10 times the TLV•, or the LFL, so for acetic acid $C = 0.25\ g/m^3$ ($TLV^{\bullet} = 0.025\ g/m^3$; $LFL = 130\ g/m^3$)

Step 7: Compute CU/Q

- $CU/Q = \frac{0.25 \times 2.1}{1.1 \times 10^4} = 4.77 \times 10^{-5}\ m^{-2}$

Step 8: Calculate the downwind distance (X_p) from the virtual point source

- From Figure 15, with $CU/Q = 4.8 \times 10^{-5}\ m^{-2}$ and weather condition F, $X_p \simeq 6.5$ km

Step 9: Calculate the hazard distance (X_a) downwind of the area source

- With $X_p = 6.5$ km and $r = 0.12$ km, then $X_a = X_p - 10\ r = 6.5\ km - 10\ (0.12\ km) = 5.3$ km

Step 10: Calculate the plume hazard half-width $(W/2)_{max}$

- Use Table 8
- With $Q = 1.1 \times 10^4$ g/s and $U = 2.1$ m/s then $Q/U = \frac{1.1 \times 10^4}{2.1} = 5240$ g/m
- Then for weather condition F, the closest Q/U value is between 5000 and 10 000 g/m, which gives $(W/2)_{max} \simeq 140$ m

Step 11: Determine the time since the spill

- $t = 5\ min \times 60 = 300$ s

Step 12: Calculate the distance travelled (X_t) by the vapour plume since the time of the accident

- Using Figure 18, with $t = 300$ s and $U = 7.5$ km/h, then $X_t = 0.6$ km (more accurately from $Ut = 2.1\ m/s \times 300\ s = 630\ m = 0.63\ km$)

Step 13: Map the hazard zone

- This is done by drawing a rectangular area with dimensions of twice the maximum plume hazard half-width (140 m) by the maximum hazard distance downwind of the area source (5.3 km) along the direction of the wind, as shown in Figure 19
- If the wind is reported to be fluctuating by 20° about 315° (or from 315° $\pm$ 10°), the hazard zone is defined as shown in Figure 20
- Note that the plume has only travelled 0.63 km in the 5 minutes since the spill. At a wind speed of 7.5 km/h, there remain 37 minutes before the plume reaches the maximum downwind hazard distance of 5.3 km

FIGURE 19

ACETIC ACID

HAZARD AREA FOR STEADY WINDS, EXAMPLE PROBLEM

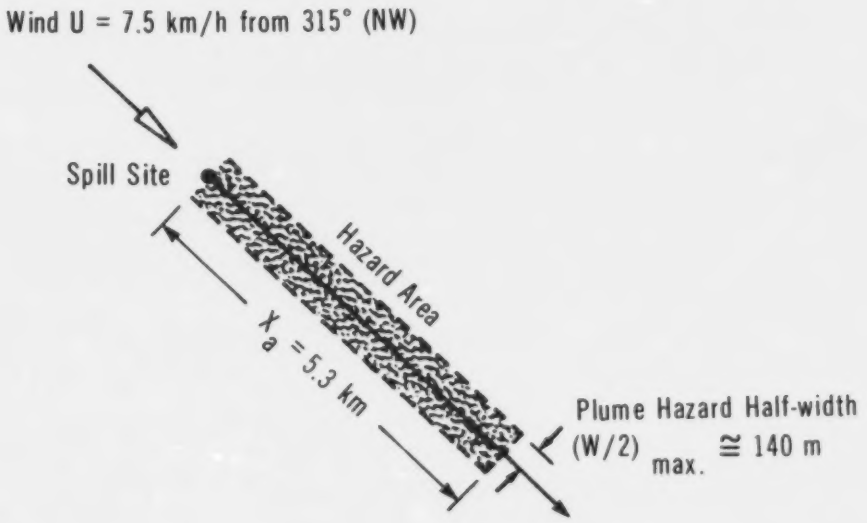
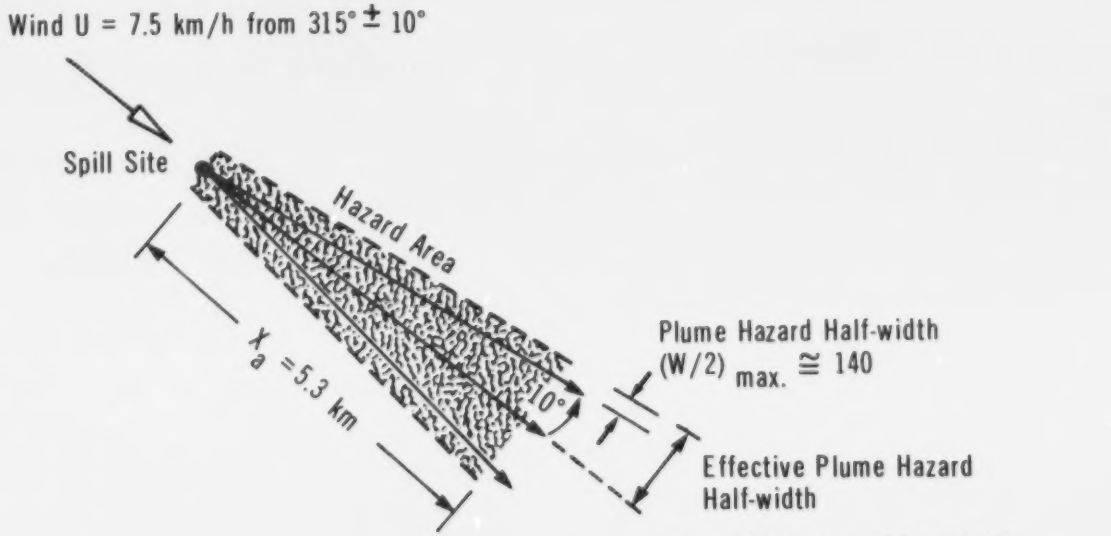


FIGURE 20

ACETIC ACID

HAZARD AREA FOR UNSTEADY WINDS, EXAMPLE PROBLEM



$= X_a \times 1000 \times \tan 10° + (W/2)_{max}$

$= \frac{5.3 \times}{} 1000 \times \tan 10° + \frac{140}{}$

$= \frac{1075}{}$ m or 1.1 km

5.4 Behaviour in Water

5.4.1 Introduction. When spilled on a water surface, acetic acid mixes rapidly and the spill is diluted. This mixing can generally be described by classical diffusion equations with one or more diffusion coefficients. In rivers, the principal mixing agent is stream turbulence, while in calm water mixing takes place by molecular diffusion.

To estimate pollutant concentration in a river downstream from a spill, the turbulent diffusion has been modelled. The model employed is strictly applicable to neutrally buoyant liquids and solids that dissolve in water. Consequently, the model is applicable to acetic acid.

The one-dimensional model uses an idealized rectangular channel section and assumes a uniform concentration of the pollutant throughout the section. Obviously, this applies only to points sufficiently far downstream of the spill where mixing and dilution have distributed the pollutant across the entire river channel. The model is applicable to rivers where the ratio of width to depth is less than 100 (W/d <100) and assumes a Manning's roughness coefficient of 0.03. Details of the model are outlined in the Introduction Manual.

No modelling has been carried out for molecular diffusion in still water. Rather, nomograms have been prepared to define the hazard zone and the average concentration within the hazard zone as a function of spill size, but independent of time.

5.4.2 Nomograms. The following nomograms are presented to calculate pollutant concentrations in non-tidal rivers and in lakes (still water).

Non-tidal Rivers

Figure 22: distance versus time for a range of average stream velocities

Figure 23: hydraulic radius versus channel width for a range of stream depths

Figure 24: hydraulic radius versus diffusion coefficient for a range of average stream velocities

Figure 25: alpha* versus diffusion coefficient for various time intervals

Figure 26: alpha versus delta* for a range of spill sizes

Figure 27: maximum concentration versus delta for a range of river cross-sectional areas

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* Alpha and delta are conversion factors only and are of no significance other than to facilitate calculation of downstream concentration.

Lakes or Still Water Bodies

Figure 28: volume versus radius for the hazard zone for a range of lake depths

Figure 29: average concentrations versus volume for the hazard zone for a range of spill sizes

The flow chart in Figure 21 outlines the steps required to estimate the downstream concentration after a spill and identifies the nomograms to be used. These nomograms (Figures 22 through 29) are described in the following subsections.

5.4.2.1 Nomograms for non-tidal rivers.

Figure 22: Time versus distance. Figure 22 presents a simple relationship between average stream velocity, time, and distance. Using an estimate of average stream velocity (U), the time (t) to reach any point of interest, at some distance (X) downstream of the spill, can be readily obtained from Figure 22.

Figure 23: Hydraulic radius versus channel width. The model used to estimate downstream pollutant concentration is based on an idealized rectangular channel of width (W) and depth (d).

The hydraulic radius (r) for the channel is required in order to estimate the turbulent diffusion coefficient (E). The hydraulic radius (r) is defined as the stream cross-sectional area (A) divided by the wetted perimeter (P). Figure 23 is a nomogram for computation of the hydraulic radius (r) using the width and depth of the idealized river cross-section.

Figure 24: Diffusion coefficient versus hydraulic radius. Figure 24 permits calculation of the longitudinal diffusion coefficient (E), knowing the hydraulic radius (r) from Figure 23 and the average stream velocity (U).

Figure 25: Alpha versus diffusion coefficient. Figure 25 is used to estimate a conversion factor, alpha, (α), which is a function of the diffusion coefficient (E) and the time (t) to reach the point of interest downstream of the spill.

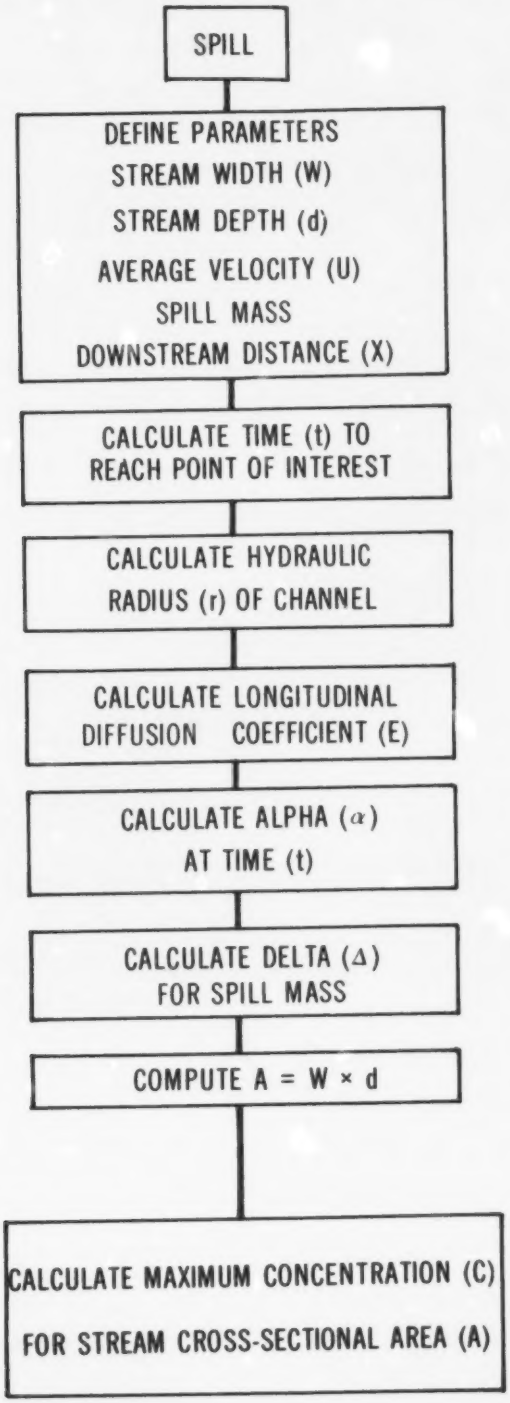
Figure 26: Alpha versus delta. A second conversion factor, delta (Δ), must be estimated from Figure 26 to allow determination of the pollutant concentration at the point of interest. Delta (Δ) is a function of alpha (α) and the spill size.

Figure 27: Maximum concentration versus delta. Figure 27 represents the final step for calculation of the maximum downstream pollutant concentration (C) at the point of interest. Using the factor delta (Δ) and knowing the stream-cross sectional area

FIGURE 21

ACETIC ACID

FLOW CHART TO DETERMINE POLLUTANT CONCENTRATION IN NON-TIDAL RIVERS


SPILL
DEFINE PARAMETERS
STREAM WIDTH (W)
STREAM DEPTH (d)
AVERAGE VELOCITY (U)
SPILL MASS
DOWNSTREAM DISTANCE (X)
CALCULATE TIME (t) TO REACH POINT OF INTEREST
CALCULATE HYDRAULIC RADIUS (r) OF CHANNEL
CALCULATE LONGITUDINAL DIFFUSION COEFFICIENT (E)
CALCULATE ALPHA (α) AT TIME (t)
CALCULATE DELTA (Δ) FOR SPILL MASS
COMPUTE A = W × d
CALCULATE MAXIMUM CONCENTRATION (C) FOR STREAM CROSS-SECTIONAL AREA (A)

Step 1: Observed or Estimated

W = _____ m

d = _____ m

U = _____ m/s

MASS = _____ tonnes

X = _____ m

Step 2: Use Figure 22

t = _____ minutes

Step 3: Use Figure 23

r = _____ m

Step 4: Use Figure 24

E = _____ m^2/s

Step 5: Use Figure 25

α = _____

Step 6: Use Figure 26

Δ = _____

Step 7: Compute stream cross-sectional Area (A)

A = W × d _____ m^2

Step 8: Use Figure 27

C = _____ ppm

FIGURE 22

ACETIC ACID

TIME vs DISTANCE

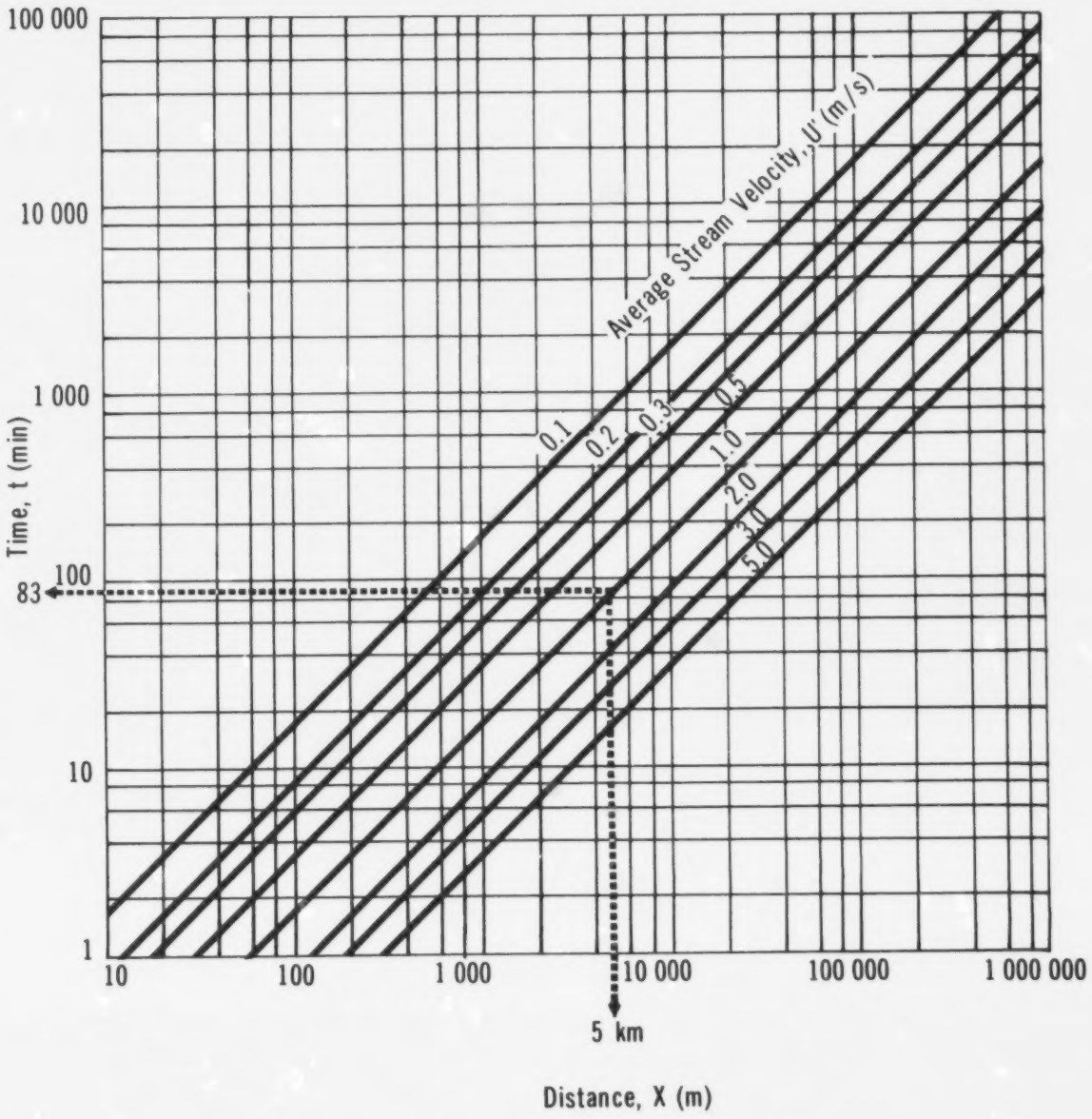


FIGURE 23

ACETIC ACID

HYDRAULIC RADIUS VS CHANNEL WIDTH

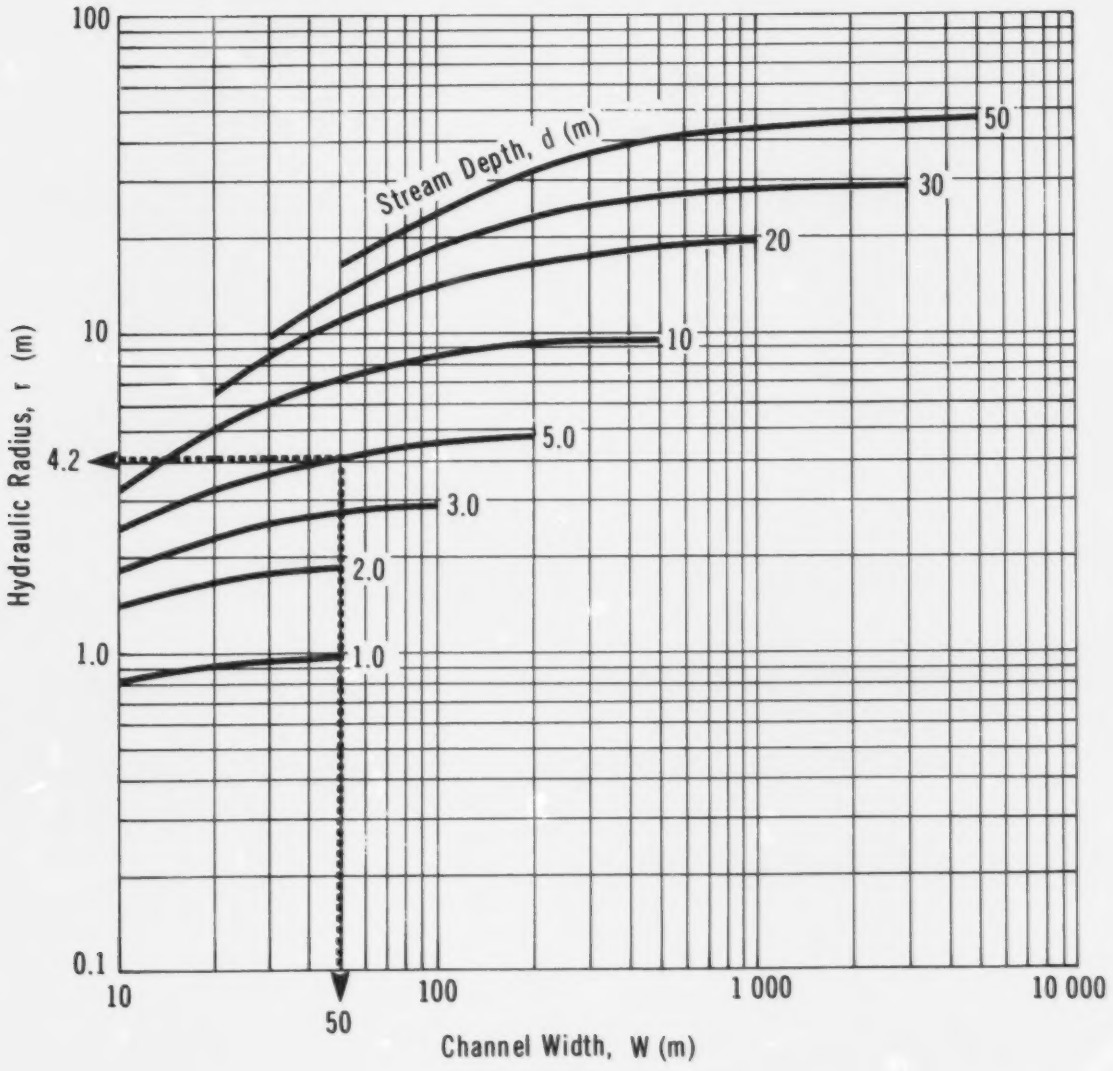


FIGURE 24

ACETIC ACID

DIFFUSION COEFFICIENT VS HYDRAULIC RADIUS

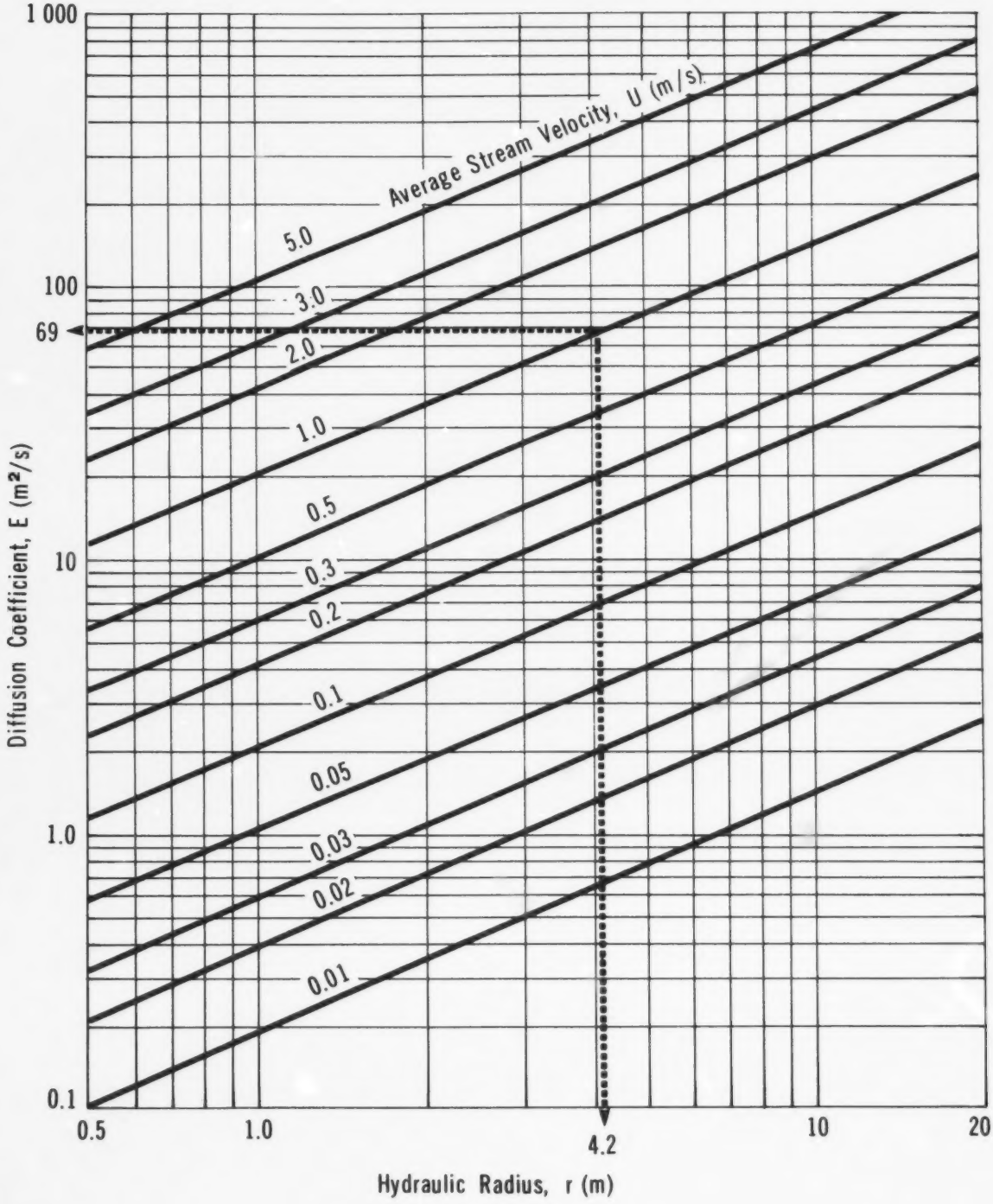


FIGURE 25

ACETIC ACID

ALPHA vs DIFFUSION COEFFICIENT

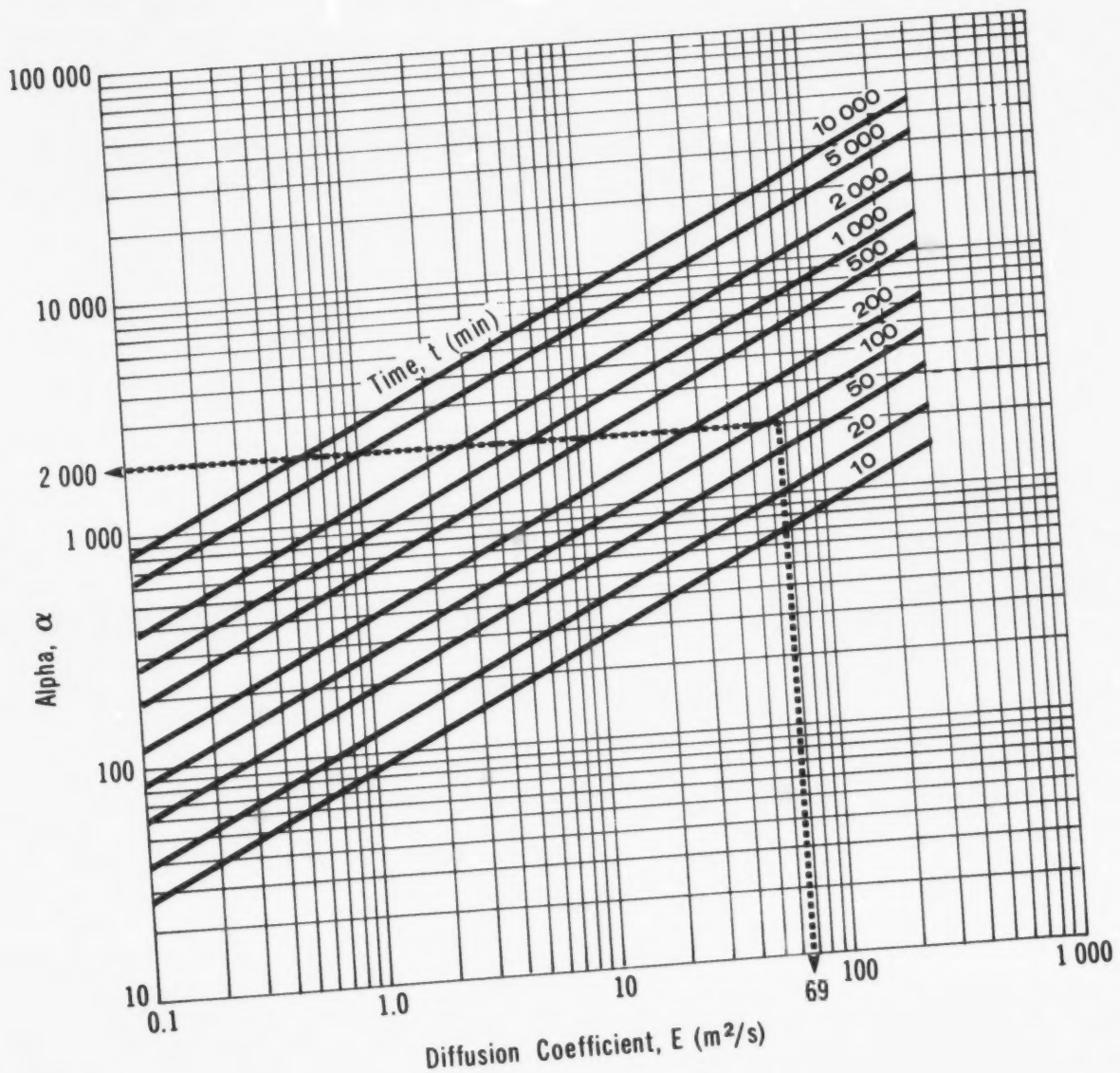


FIGURE 26

ACETIC ACID

ALPHA vs DELTA

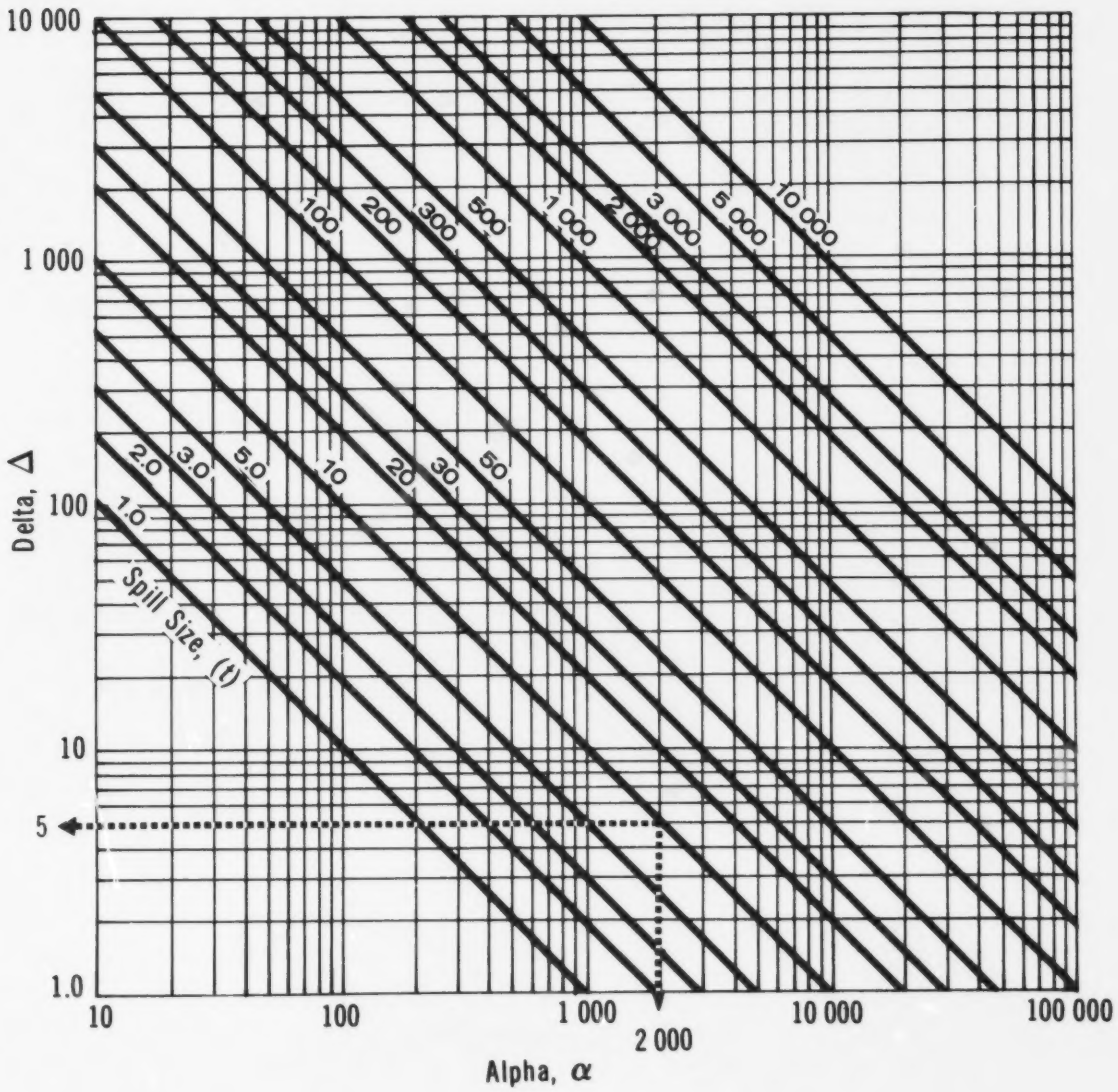
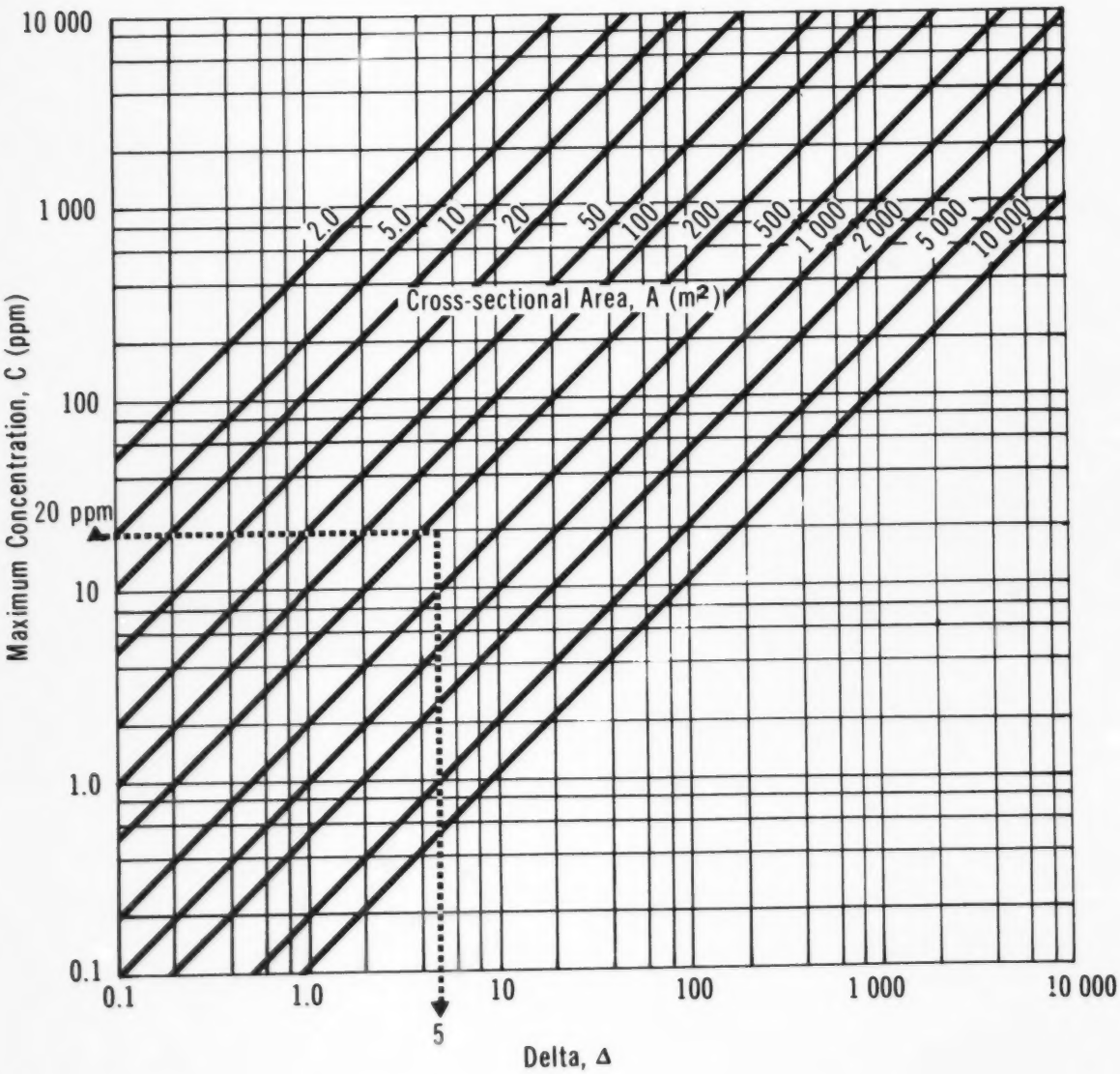


FIGURE 27

ACETIC ACID

MAXIMUM CONCENTRATION vs DELTA



(A), the concentration (C) is readily obtained from the nomogram. The value obtained from Figure 27 applies to neutrally buoyant liquids or solids and will vary somewhat for other pollutants which are heavier or lighter than water.

5.4.2.2 Nomograms for lakes or still water bodies.

Figure 28: Volume versus radius. The spill of a neutrally buoyant liquid in a lake in the absence of wind and current has been idealized as a cylinder of radius (r) and length (d), equivalent to the depth of the lake at the point of the spill. The volume of water in the cylinder can be obtained from Figure 28. The radius (r) represents the distance from the spill to the point of interest.

Figure 29: Average concentration versus volume. For a known volume of water (within the idealized cylinder of radius (r) and length (d)), the average concentration of pollutant (C) can be obtained from Figure 29 for a known mass of spill. This assumes the pollutant is spread evenly throughout the cylinder. For pollutants that are more or less dense than water, the actual concentration at the bottom would be higher or lower, respectively.

5.4.3 Sample Calculations.

5.4.3.1 Pollutant concentration in non-tidal rivers. A 20 tonne spill of 50 percent acetic acid solution has occurred in a river. The stream width is 50 m and the stream depth is 5 m. The average stream velocity is estimated at 1 m/s. What is the maximum concentration expected at a water intake located 5 km downstream?

Solution

Step 1: Define parameters

- W = 50 m
- d = 5 m
- U = 1 m/s
- spill mass = 20 tonnes of 50 percent solution, contains the equivalent of 10 tonnes of acetic acid
- X = 5000 m

Step 2: Calculate the time to reach the point of interest

- Use Figure 22
- With X = 5000 m and U = 1 m/s, t = 83 min

FIGURE 28

ACETIC ACID

VOLUME vs RADIUS

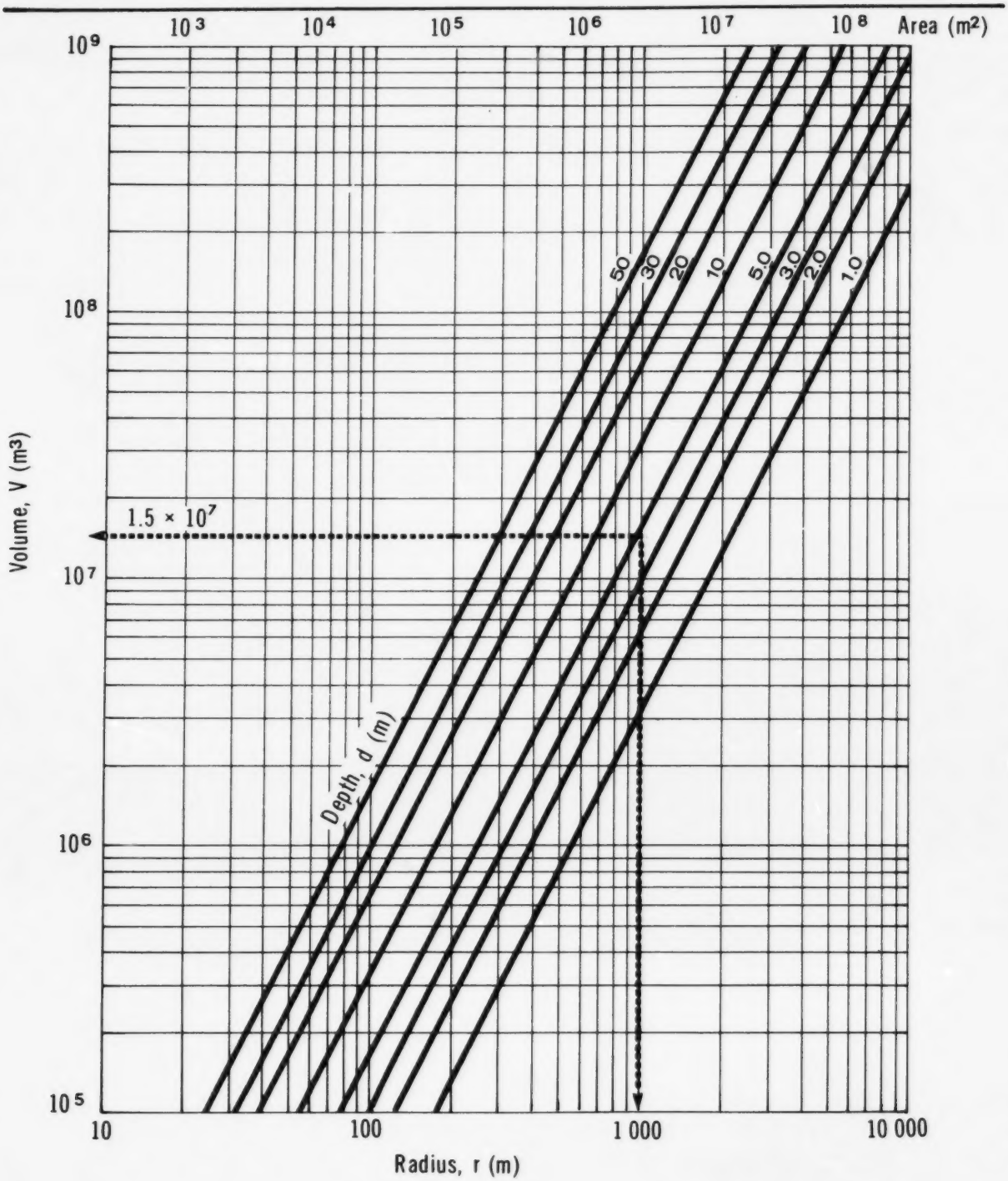
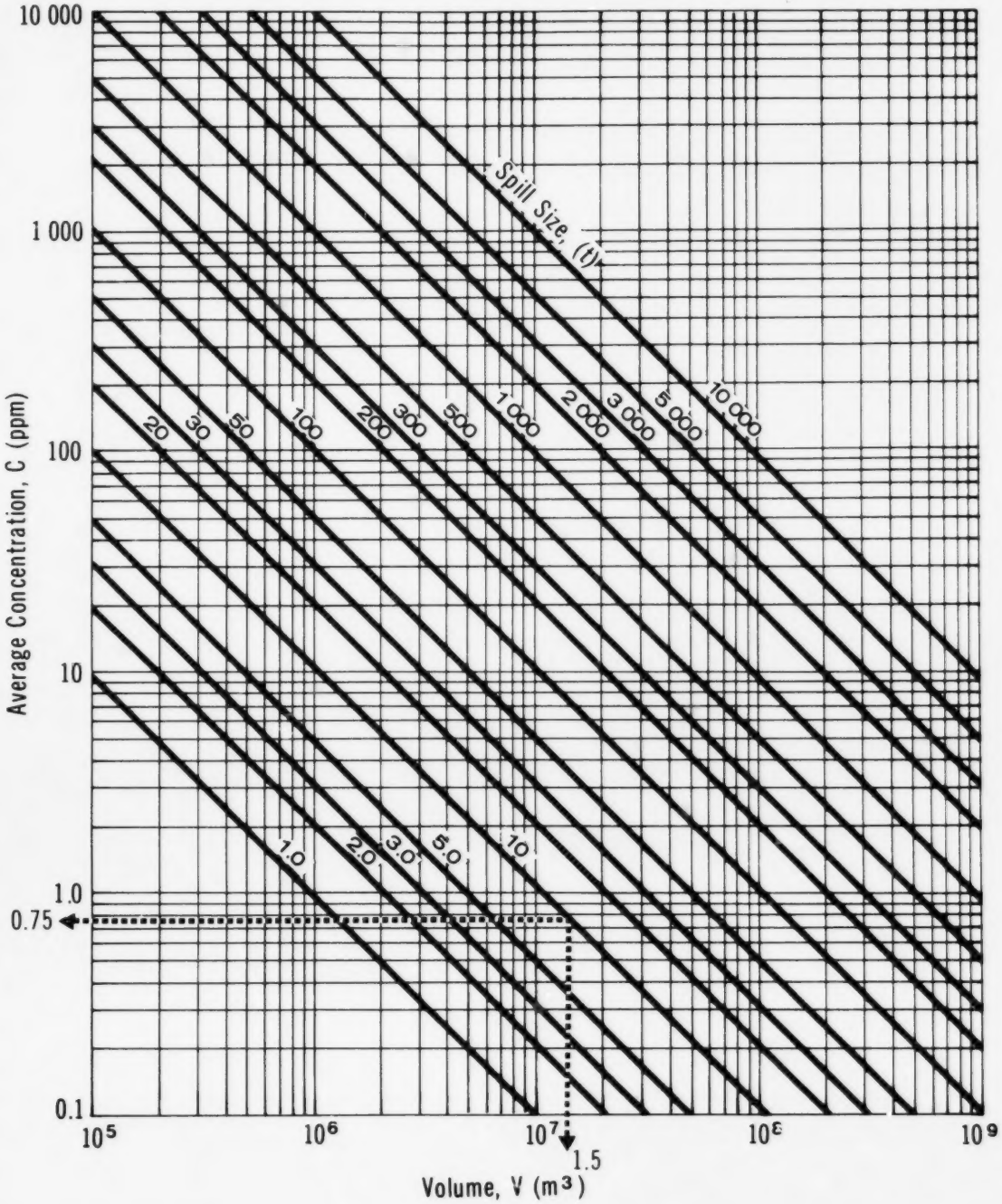


FIGURE 29

ACETIC ACID

AVERAGE CONCENTRATION vs VOLUME



Step 3: Calculate the hydraulic radius (r)

- Use Figure 23
- With W = 50 m and d = 5 m, r = 4.2 m

Step 4: Calculate the longitudinal diffusion coefficient (E)

- Use Figure 24
- With r = 4.2 m and U = 1 m/s, E = 69 m^2/s

Step 5: Calculate alpha (α)

- Use Figure 25
- With E = 69 m^2/s and t = 83 min, (α) = 2000

Step 6: Calculate delta (Δ)

- Use Figure 25
- With alpha (α) = 2000 and spill mass = 10 tonnes, delta (Δ) = 5

Step 7: Compute the stream cross-sectional area (A)

- A = W x d = 50 x 5 = 250 m^2

Step 8: Calculate the maximum concentration (C) at the point of interest

- Use Figure 27
- With Δ = 5 and A = 250 m^2, C = 20 ppm

5.4.3.2 Average pollutant concentration in lakes or still water bodies. A 20 tonne spill of 50 percent acetic acid solution has occurred in a lake. The point of interest is located on the shore approximately 1000 m from the spill. The average depth between the spill site and the point of interest is 5 m. What is the average concentration which could be expected?

Solution

Step 1: Define parameters

- d = 5 m
- r = 1000 m
- spill mass = 10 tonnes (equivalent weight of acetic acid)

Step 2: Determine the volume of water available for dilution

- Use Figure 28
- With r = 1000 m, d = 5 m, the volume is approximately 1.5 x 10^7 m^3

Step 3: Determine the average concentration

- Use Figure 29
- With V = 1.5 x 10^7 m^3 and spill mass = 10 tonnes, the average concentration is 0.75 ppm

5.5 Subsurface Behaviour: Penetration into Soil

5.5.1 Mechanisms. The principles of contaminant transport in soil and their application to this work are presented in the Introduction Manual. Special considerations related to the spill of acetic acid onto soil and its transport downward through the soil are presented here.

Acetic acid is shipped as a liquid, either pure or diluted with water. When spilled at temperatures above its freezing point, it will readily infiltrate the soil and will be diluted by precipitation or by water used to flush the spill site. The fluid will move downward through the soil and toward the groundwater table.

If the soil surface is saturated with moisture at the time of the spill, as might be the case after a rainfall, the spilled chemical will run off or remain ponded.

For this work, the soils have been assumed to be at field capacity. This situation provides very little interstitial water to dilute the chemical during transport or to impede its downward movement and thus represents "worst case" analysis.

During transport through the soil, acetic acid will dissolve some of the carbonate soil materials. The acid will be neutralized to some degree, with adsorption of protons and acetate ions occurring on clay minerals to some degree. However, the analysis used here neglects these retarding factors. Significant amounts of acid are expected to remain for transport down toward the groundwater table.

Upon reaching the groundwater table, the acid will continue to move, now in the direction of groundwater flow. A contaminated plume will be produced, with dilution and diffusion serving to reduce the acid concentrations. This is shown schematically in Figure 30.

5.5.2 Equations Describing Acetic Acid Movement into Soil. The equations and assumptions used to describe contaminant movement downward through the unsaturated soil zone toward the groundwater table have been described in the Introduction Manual. Transport velocities have been based on Darcy's Law assuming saturated piston flow.

5.5.3 Saturated Hydraulic Conductivity of Acetic Acid in Soil. The saturated hydraulic conductivity (K_o), in m/s, is given by:

$$K_o = \frac{(\rho g)k}{\mu}$$

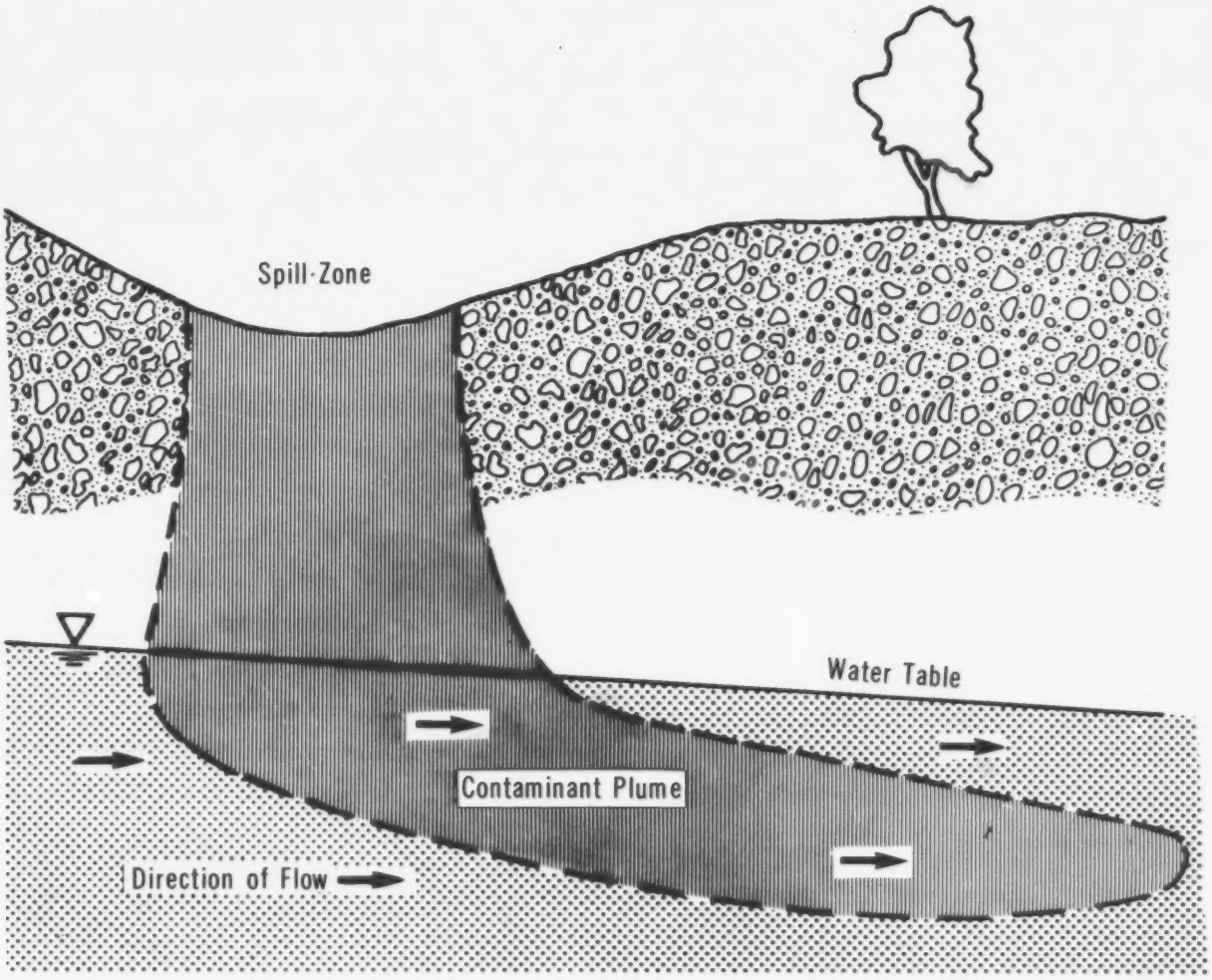
where:

- k = intrinsic permeability of the soil (m^2)
- μ = absolute viscosity of the fluid (Pa•s)
- ρ = mass density of the fluid (kg/m^3)
- g = acceleration due to gravity = 9.81 m/s^2

FIGURE 30

ACETIC ACID

SCHEMATIC SOIL TRANSPORT



Soil: Coarse Sand

–Porosity (n) = 0.35

–Intrinsic Permeability (k) = 10^{-9} m^2

–Field Capacity (θ_{fc}) = 0.075

The fluids involved are pure acetic acid, 10 percent by weight acetic acid, and water. The water calculations represent the extreme as acetic acid is diluted. The appropriate properties of acetic acid are given in the chart below.

Property	Acetic Acid		Water (20°C)
	Pure (20°C)	10 percent (20°C)	
Mass density (ρ), kg/m^3	1049	1012	998
Absolute viscosity (μ), Pa·s	1.28×10^{-3}	1.23×10^{-3}	1.0×10^{-3}
Saturated hydraulic conductivity (Ko), m/s	$(0.8 \times 10^7)k$	$(0.8 \times 10^7)k$	$(0.98 \times 10^7)k$

5.5.4 Soils. The Introduction Manual describes the three soils selected for this work. Their relevant properties are:

Property	Soil Type		
	Coarse Sand	Silty Sand	Clay Till
Porosity (n), m^3/m^3	0.35	0.45	0.55
Intrinsic permeability (k), m^2	10^{-9}	10^{-12}	10^{-15}
Field capacity (θ_{fc}), m^3/m^3	0.075	0.3	0.45

5.5.5 Penetration Nomograms. Nomograms for the penetration of acetic acid into the unsaturated zone above the groundwater table were prepared for each soil. They present penetration time (t_p) plotted against depth of penetration (B). Because of the methods and assumptions used, the penetration depth should be considered as a maximum depth in time t_p.

A flowchart for the use of the nomograms is presented in Figure 31. The nomograms are presented as Figures 32, 33, and 34. The water line on the nomograms represents the maximum penetration of water at 20°C in time t_p. It is a limiting condition as acetic acid becomes diluted with water.

FIGURE 31

ACETIC ACID

FLOWCHART FOR NOMOGRAM USE

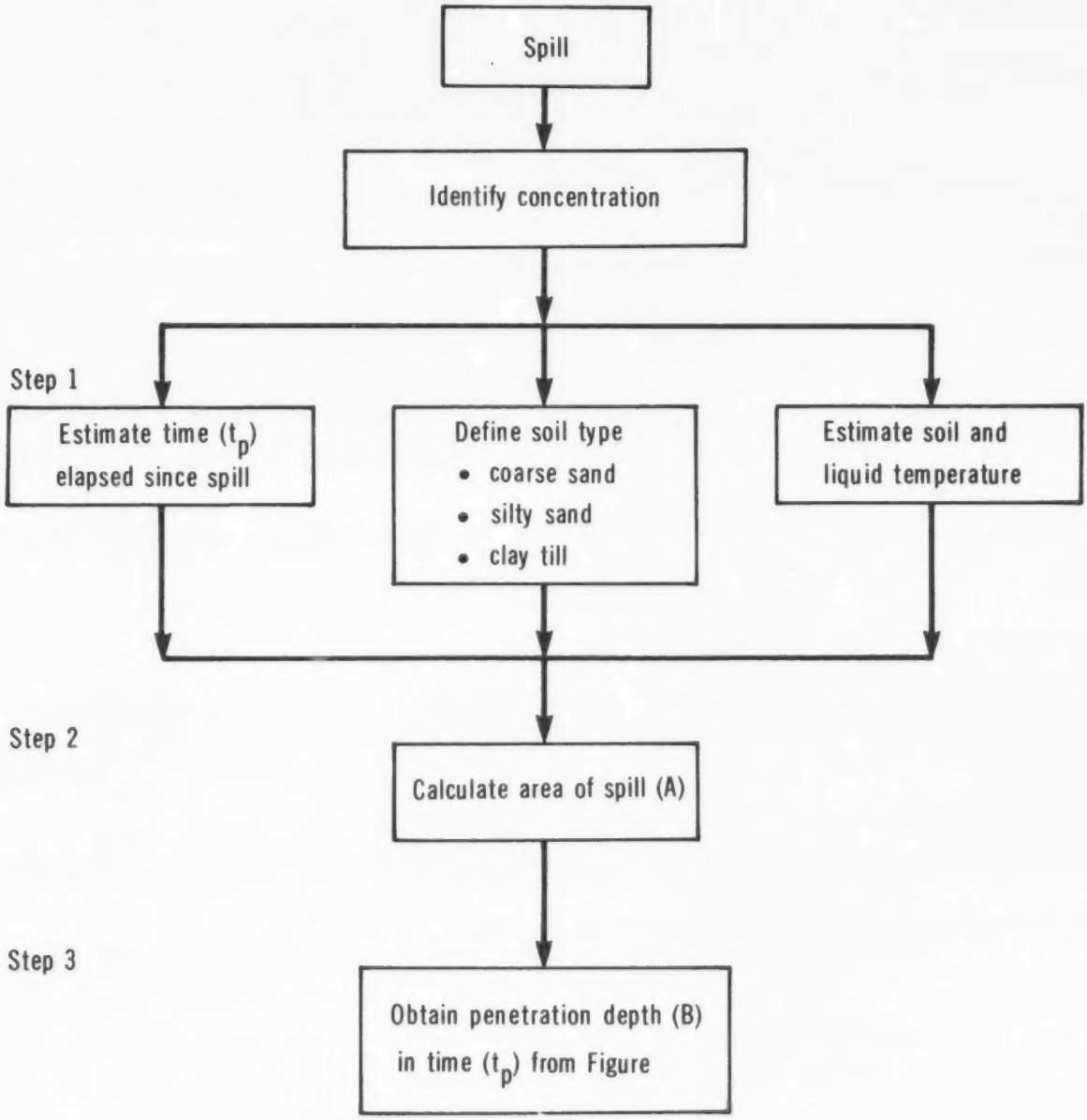


FIGURE 32

ACETIC ACID

PENETRATION IN COARSE SAND

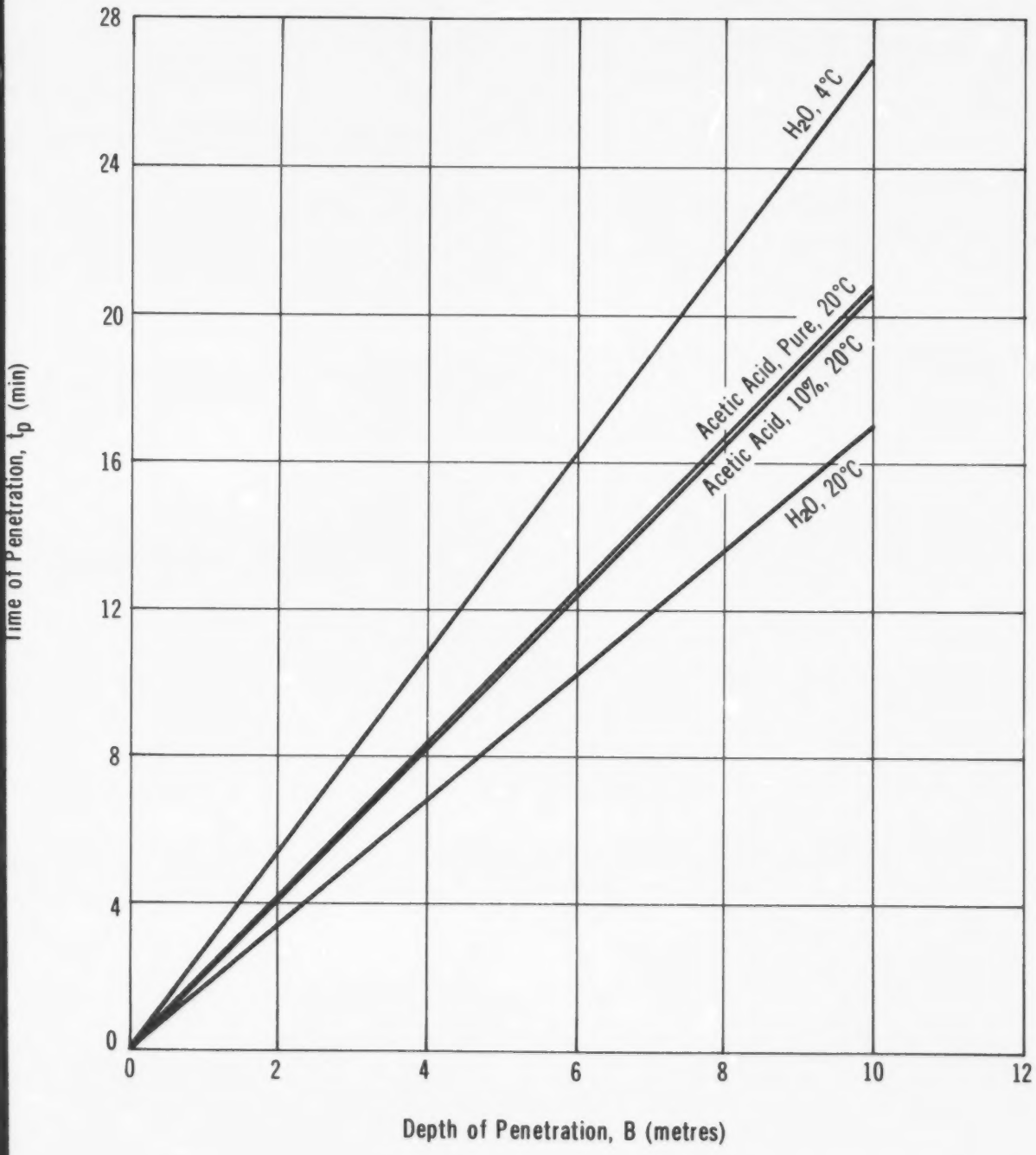


FIGURE 33

ACETIC ACID

PENETRATION IN SILTY SAND

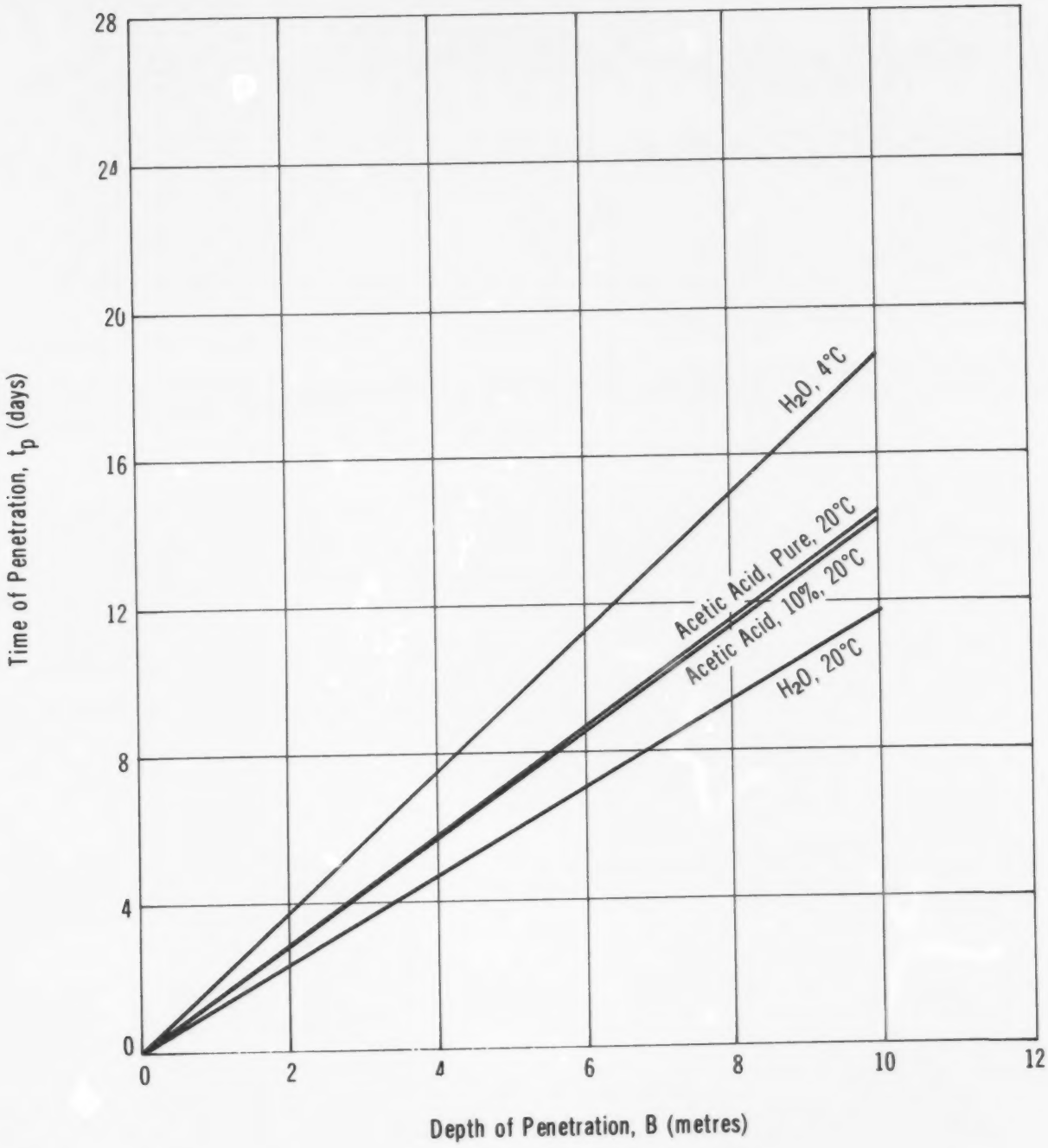
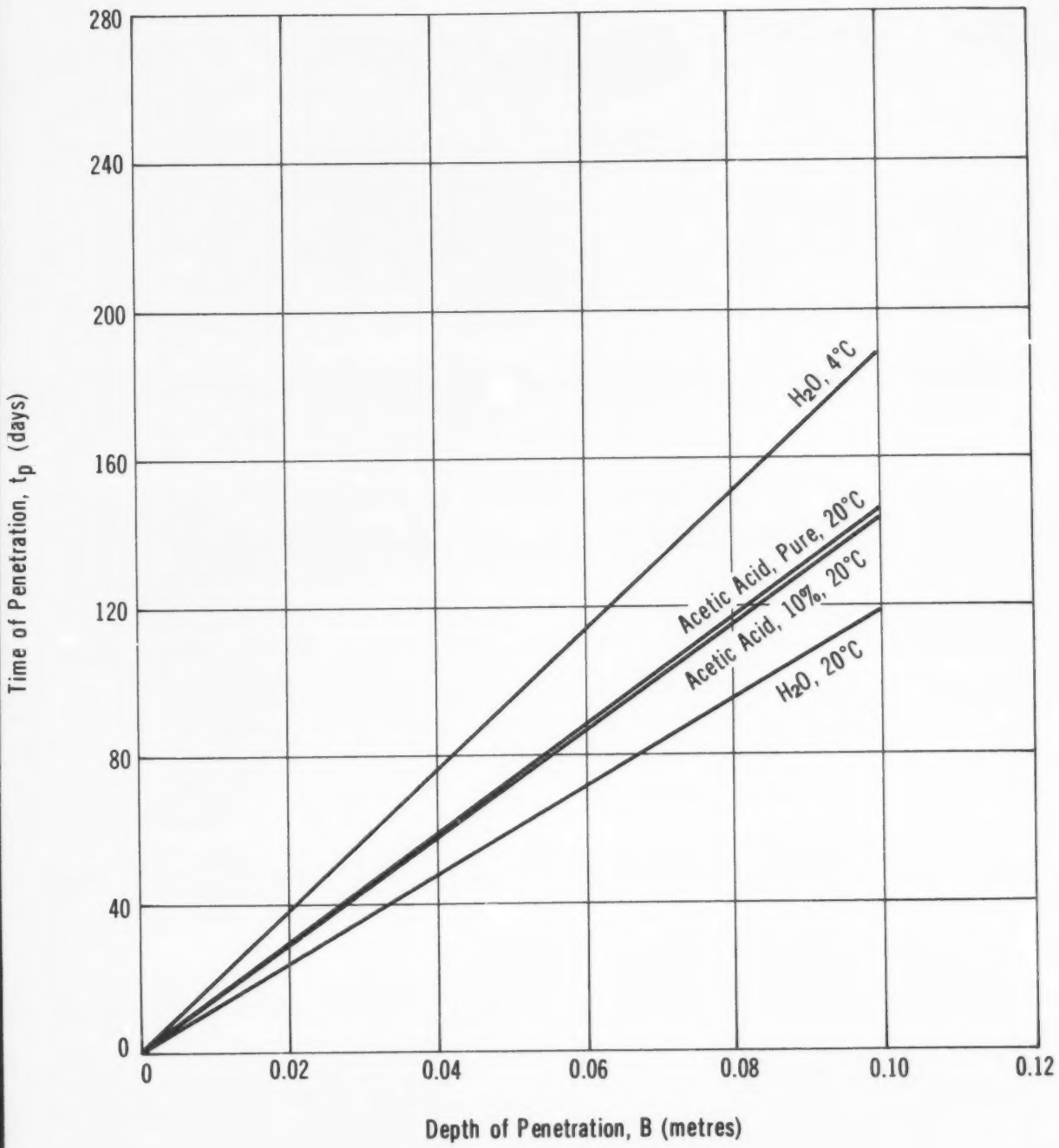


FIGURE 34

ACETIC ACID

PENETRATION IN CLAY TILL



5.5.6 Sample Calculation. A 20 tonne spill of acetic acid has occurred on coarse sand. The temperature is 20°C; the spill radius is 8.6 m. Calculate the depth of penetration 20 minutes after the spill.

Solution

Step 1: Define parameters

- Mass spilled = 20 000 kg (20 tonnes)
- T = 20°C
- r = 8.6 m
- Soil = coarse sand
- Groundwater table depth (d) = 13 m
- Time since spill (t_p) = 20 m

Step 2: Calculate the area of spill

- $A = \pi r^2 = 232\ m^2$

Step 3: Estimate the depth of penetration (B) at time (t_p)

- For coarse sand, B = 9.7 m at t_p = 20 min
- Groundwater table has not been reached in this time

6 ENVIRONMENTAL DATA

6.1 Suggested or Regulated Limits

6.1.1 Water. A drinking water limit of 128 ppm has been recommended in the U.S. (OHM-TADS 1981).

6.1.2 Air. The Ontario environmental air limit is 2.5 mg/m^3 (Ontario E.P. Act 1971).

6.2 Aquatic Toxicity

6.2.1 U.S. Toxicity Rating. Acetic acid has been assigned a TL_m96 of 10 to 100 ppm (RTECS 1979).

6.2.2 Measured Toxicities.

6.2.2.1 Freshwater toxicity.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Kill Data					
50	24	Brook trout	lethal		WQC 1963
114	24	Minnow	lethal		WQC 1963
423	20	Goldfish	lethal		Verschueren 1984
Fish Toxicity Tests					
>100	72	Fathead minnow	no toxic effect	50°F	EPA 440/9-75-009
100	96	Goldfish	TL_m		Little 1970
100-200	96	Creek chub	TL_m	Detroit river water	Little 1970
75	96	Bluegill	TL_m		Cairns 1968
75	96	Sunfish	TL_m	18-20°C, soft water	WQC 1963
286	24	Goldfish	LC_{50}	-	DPIMR 1983
270	72	Channel catfish	TL_m	25°C	DPIMR 1983
251	24-96	Mosquito fish	TL_m	turbid	DPIMR 1983
624	72	Channel catfish	LC_{100}	25°C	DPIMR 1983
175	1	Fathead minnow	LC_{50}	18-22°C, reconstituted water, pH <5.9	Mattson 1976

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
106	24-48	Fathead minnow	LC_{50}	18-22°C, reconstituted water, pH <5.9	Mattson 1976
79	72-96	Fathead minnow	LC_{50}	18-22°C, pH <5.9, reconstituted water	Mattson 1976
>315	1	Fathead minnow	LC_{50}	pH <5.9, 18-22°C, Lake Superior water	Mattson 1976
122	24	Fathead minnow	LC_{50}	pH <5.9, 18-22°C, Lake Superior water	Mattson 1976
92	48	Fathead minnow	LC_{50}	pH <5.9, 18-22°C, Lake Superior water	Mattson 1976
88	72-96	Fathead minnow	LC_{50}	pH <5.9, 18-22°C, Lake Superior water	Mattson 1976
Invertebrates					
80-150	120	Daphnia	immobilized	Lake Erie	WQCDB-5 1973
47	24	*Daphnia magna*	TL_m	-	Verschueren 1984
Microorganisms					
74	-	Diatom (*Navicula seminulum*)	50% reduction in growth	soft water, 20°C	DPIMR 1983
>4	12	Algae (*Nitzschia linearis*)	LC_{50}	-	DPIMR 1983
74	-	Algae (*Nitzschia linearis*)	LC_{50}	synthetic water	WQCDB-5 1973
2850	-	Bacteria (*Pseudomonas putida*)	inhibition of cell multiplication	-	Verschueren 1984

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
90	-	Algae *(Microcystis aeruginosa)*	inhibition of cell multiplication	-	Verschueren 1984
4000	-	Green algae *(Scenedesmus quadricauda)*	inhibition of cell multiplication	-	Verschueren 1984
1350	-	Protozoa *(Uronema parduczi)*	inhibition of cell multiplication	-	Verschueren 1984
78	-	Protozoa *(Entosiphon sulcatum)*	inhibition of cell multiplication	-	Verschueren 1984
350	-	*Chlorella pyranoidosa*	toxic	-	Jones 1971

6.2.2.2 Saltwater toxicity.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
32	48	Brine shrimp	TL_m	static	Price 1974
100-300	48	Shrimp	LC_{50}	aerated	Portman 1970
42	24	Brine shrimp	TL_m	static	DPIMR 1983
>100	96	Shore crab *(Carcinus maenus)*	LC_{50}	continuous flow	WQCDB-5 1973
>100	96	Crab *(Crangon crangon)*	LC_{50}	continuous flow	WQCDB-5 1973
6	-	Amphipod *(Limnea ovata)*	perturbation level	-	Verschueren 1984
14	-	Amphipod *(Gammarus pulex)*	perturbation level	-	Verschueren 1984

6.3 Effect Studies

Hardness in water is antagonistic to freshwater toxicity, raising the concentration required for given TL_m values (WQC 1963).

The toxicity of acetic acid on an insect (mosquito larvae, *Culex* sp.) in water has been determined to be 1500 mg/L in 24 hours (Verschueren 1984).

The effect of the vapour on a number of plant species has been determined. The 2-hour EC_{50} (for visible leaf damage) is as follows (Verschueren 1984):

Plant	EC_{50} (ppm)
Wheat	9.3
Alfalfa	3.1
Tobacco	16.5
Soybean	8.1
Corn	20.1

6.4 Degradation

6.4.1 Biochemical Oxygen Demand.

B.O.D. Oxygen/ Acetic Acid (w/w)	% of Theoretical B.O.D.	Time Days	Seed	Method	Reference
>1	66	5	sewage seed	saltwater	Price 1974
>1	88	10	sewage seed	saltwater	Price 1974
>1	100	20	sewage seed	saltwater	Price 1974
>1	76	5	sewage seed	freshwater	Price 1974
>1	82	10	sewage seed	freshwater	Price 1974
>1	85	15	sewage seed	freshwater	Price 1974
>1	96	20	sewage seed	freshwater	Price 1974
>1	50	0.5	phenol-acclimated activated sludge	-	DPIMR 1983
>1	53	1-5	activated sludge	respirometer	DPIMR 1983
0.7	-	5	-	-	DPIMR 1983
0.9	-	20	-	-	DPIMR 1983
0.34-0.88	-	5	sewage seed	-	DPIMR 1983
1	-	-	chemical	C.O.D.	DPIMR 1983

Oxygen deficiencies may result from rapid biochemical and chemical oxygen demand. High concentrations may cause extremely low pH, killing biota and interfering with coagulation (OHM-TADS 1981).

6.5 Long-term Fate and Effects

Natural waters will neutralize dilute solutions to acetate salts. Acetic acid shows no potential for biological accumulation or food chain contamination (OHM-TADS 1981).

7 HUMAN HEALTH

Acetic acid is a clear, colourless liquid with a pungent, vinegar-like odour. It is a very common and widely used industrial chemical found in industries as diverse as cellulose production and food processing.

Acetic acid is extremely corrosive on contact with living tissue by any route of exposure. Its health effects are primarily local in nature, although cases of bronchitis have been reported to develop at some time following acute exposures (Doc. TLV 1981).

It is likely that the well-known local effects of acetic acid account for the paucity of research and review publications concerning the toxic effects of this chemical. No data were found in the literature on acetic acid's mutagenicity or teratogenicity nor its carcinogenic potential. Acetic acid has been reported in the EPA TSCA Inventory.

The toxicological data summarized here have been extracted from reliable standard reference sources. It should be noted that some of the data are for chronic (long-term), low-level exposures and may not be directly applicable to spill situations. Only acute (short-term) exposure data are given for non-human mammalian species, to support interpretation of the human data where appropriate.

7.1 Recommended Exposure Limits

The exposure standards for acetic acid are based upon its irritant properties. Canadian provincial guidelines generally are similar to those of the USA-ACGIH, unless indicated otherwise.

Guideline (Time)	Origin	Recommended Level	Reference
Time-weighted Averages (TWA)			
TLV•	USA-ACGIH	10 ppm (25 mg/m^3)	TLV 1983
TWA	USA-OSHA	10 ppm	NIOSH/OSHA 1981
Short-term Exposure Limits (STEL)			
STEL (15 min)	USA-ACGIH	15 ppm (37 mg/m^3)	TLV 1983
Other Human Toxicities			
IDLH (inhalation)	USA-NIOSH	1000 ppm	NIOSH Guide 1978
TD_{LO} (ingestion)		1.47 mg/kg	RTECS 1979

Inhalation Toxicity Index

The Inhalation Toxicity Index (ITI) is a measure of the potential of a substance to cause injury by inhalation. It is calculated as follows:

ITI = 1315.12 (Vapour Pressure, in mm Hg / TLV•, in ppm)

At 36°C, ITI = 1315.12 (9.7 mm Hg / 10 ppm)

$= 1.3 \times 10^3$

7.2 Irritation Data

7.2.1 Skin Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
50 mg (24 h)	Mild irritation	RTECS 1979
Concentrated acetic acid	Severe damage	NIOSH/OSHA 1981
SPECIES: Rabbit		
1060 mg/kg	LD_{50}	Patty 1982
525 mg	Severe irritation - open skin	DPIMR 1983
50 mg (24 h)	Mild irritation	RTECS 1979
SPECIES: Guinea Pig		
80 percent	Severe burns	NIOSH/OSHA 1981
80 to 50 percent	Moderate to severe burns	NIOSH/OSHA 1981
<50 percent	Relatively mild injury	NIOSH/OSHA 1981
5 to 10 percent	No injury	NIOSH/OSHA 1981

7.2.2 Eye Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
Glacial (100 percent) acetic acid	Permanent corneal opacification	NIOSH/OSHA 1981

Exposure Level (and Duration)	Effects	Reference
4 to 10 percent acetic acid solution	Immediate pain and conjunctival hyperemia, sometimes with injury of corneal epithelium	NIOSH/OSHA 1981
10 to 15 ppm (vapour)	Irritation	NIOSH/OSHA 1981
SPECIES: Rabbit		
Glacial (100 percent) acetic acid	Severe injury	NIOSH/OSHA 1981
50 µg	Severe irritation	DPIMR 1983

7.3 Threshold Perception Properties

7.3.1 Odour. Odour Characteristics: Sharp, vinegar-like (Kirk-Othmer 1978). Odour Index: 15 000 (AAR 1981).

Parameter	Media	Concentration	Reference
Odour Threshold	in air	24 ppm	NIOSH/OSHA 1981
Odour Threshold	in air	10 ppm	NIOSH/OSHA 1981
Odour Threshold	in air	0.2 to 1 ppm	NIOSH/OSHA 1981
Lower Odour Threshold	in air	5 ppm	DPIMR 1983
Median Odour Threshold	in air	24.3 ppm	DPIMR 1983
Upper Odour Threshold	in air	80 ppm	DPIMR 1983

7.3.2 Taste. Taste Characteristics: Vinegar-like, burning, sour (Kirk-Othmer 1978).

Parameter	Media	Concentration	Reference
Upper Taste Threshold	in water	1000 ppm	DPIMR 1983
Lower Taste Threshold	in water	300 ppm	DPIMR 1983

7.4 Toxicity Studies

7.4.1 Inhalation.

Exposure Level (and Duration)	Effects	Reference
Acute Exposure		
SPECIES: Human		
800 to 1200 ppm	Cannot be tolerated for longer than 3 minutes	Doc. TLV 1981
816 ppm (3 min)	TC_{LO}	RTECS 1979
200 ppm	Severe effects	Verschueren 1984
>50 ppm	Intolerable to most persons. Results in intense lacrimation and irritation of eyes, nose and throat, with pharyngeal edema and chronic bronchitis	NIOSH/OSHA 1981
50 ppm	Intolerable	NIOSH/OSHA 1981
40 ppm	Symptoms of illness	Verschueren 1984
>25 ppm	Unacclimatized humans experience extreme eye and nasal irritation	NIOSH/OSHA 1981
SPECIES: Guinea Pig		
>100 ppm (1 h)	Irritation of respiratory tract	NIOSH/OSHA 1981
SPECIES: Rat		
16 000 ppm (4 h)	Killed one out of six test rats, LC_{LO}	Doc. TLV 1981
SPECIES: Mouse		
5620 ppm (1 h)	LC_{50}	Patty 1982
>100 ppm (1 h)	Irritation of respiratory tract	NIOSH/OSHA 1981
Chronic Exposure		
SPECIES: Human		
80 to 200 ppm (7 to 12 yr)	Congestion of the pharynx	NIOSH/OSHA 1981
60 ppm, plus 1 h/d at 100 to 260 ppm (7 to 12 yr)	No injury except slight irritation of respiratory tract, stomach and skin	Doc. TLV 1981

Exposure Level (and Duration)	Effects	Reference
60 ppm, plus 1 h/d at 100 to 260 ppm (7 to 12 yr)	Conjunctivitis, bronchitis, pharyngitis and erosion of exposed teeth	Doc. TLV 1981

7.4.2 Ingestion.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
1.47 mg/kg	TD_{LO}, gastrointestinal tract effects	DPIMR 1983
1.0 mL glacial acetic acid	Perforation of esophagus	NIOSH/OSHA 1981
SPECIES: Rabbit		
1200 mg/kg	LD_{LO}	Patty 1982
SPECIES: Rat		
3310 mg/kg	LD_{50}	Patty 1982
SPECIES: Mouse		
4960 mg/kg	LD_{50}	Patty 1982

7.4.3 Mutagenicity, Teratogenicity and Carcinogenicity.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Salmonella		
Not specified	Low mutagenic potential; <0.004 revertant colonies/n mole; <70 revertant colonies at 1000 µg/plate	Verschueren 1984
SPECIES: *Saccharomyces cerevisae*		
	No mutagenic response	Patty 1982

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rabbit		
1.6 g/kg/d	No fetal abnormalities after treatment of pregnant rabbits	Patty 1982
SPECIES: Chicken		
100 mg/kg	Chicken embryos treated; no teratogenic effects noted after incubation	Patty 1982

7.5 Symptoms of Exposure

General symptoms of exposure found in most information sources have not been specifically referenced. Only those of a more specific or unusual nature have their sources indicated.

7.5.1 Inhalation.

Note: Acclimation may occur gradually to increasing concentrations.

1. Coughing (AAR 1981).
2. Irritation of nose and throat (AAR 1981).
3. Erosion of exposed teeth (GE 1980).
4. Nausea (AAR 1981).
5. Vomiting (AAR 1981).
6. Bronchial constriction (TDB (on-line) 1981).
7. Chest pain (AAR 1981).
8. Bronchopneumonia (NIOSH/OSHA 1981).
9. Pulmonary edema.

7.5.2 Ingestion.

1. Pain in the mouth, pharynx, esophagus and stomach.
2. Laryngitis.
3. Diarrhea (USDHEW 1977).
4. Bloody vomiting (USDHEW 1977).
5. Hemolysis (USDHEW 1977).

6. Hemoglobinuria (USDHEW 1977).
7. Anuria (USDHEW 1977).
8. Shock (USDHEW 1977).
9. Penetration of the esophagus.
10. Death (NIOSH/OSHA 1981).

7.5.3 Skin Contact.

1. Dermatitis (DPIMR 1981).
2. Ulcers (DPIMR 1981).
3. Skin may become blackened, hyperkeratotic (TDB (on-line) 1981).

7.5.4 Eye Contact.

1. Lacrimation.
2. Hyperemia.
3. Conjunctivitis.
4. Iritis.
5. Corneal erosion.
6. Loss of sight (NIOSH/OSHA 1981).

8 CHEMICAL COMPATIBILITY

8.1 Compatibility of Acetic Acid with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
GENERAL														
Fire		•	•										Moderate explosion hazard	Sax 1979
Heat		•												Sax 1979
SPECIFIC CHEMICALS														
Acetaldehyde	•			•									Causes polymerization of acetaldehyde	Bretherick 1979
2-Aminoethanol	•						•						In a closed container	NFPA 1978
Ammonium Nitrate		•											Ignites on warming	NFPA 1978
5-Azidotetrazole			•											Bretherick 1979
Bromine Pentafluoride		•	•											NFPA 1978
Chlorine Trifluoride			•							•			Violent, sometimes explosive reaction	NFPA 1978
Chlorosulphonic Acid	•						•						In a closed container	NFPA 1978
Chromic Acid			•										Explodes if not kept cold	NFPA 1978

8.1 Compatibility of Acetic Acid with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Ethylene Diamine	•							•					In a closed container	NFPA 1978
Ethyleneimine	•							•					In a closed container	NFPA 1978
Hydrogen Peroxide		•	•										On heating, produces peracetic acid which explodes at 110°C	NFPA 1978
Nitric Acid		•											Explodes if not kept cold	NFPA 1978
Oleum	•							•					In a closed container	NFPA 1978
Perchloric Acid					•	•				•				Leleu 1972
Phosphorus Isocyanate										•			Upon contact	NFPA 1978
Phosphorus Trichloride		•											Explosion with heat and formation of phosphine	NFPA 1978
Potassium Hydroxide										•			With a production residue of potassium hydroxide	Leleu 1976
Potassium Tert-Butoxide		•											Ignition 3 min after contact with acetic acid vapour	Bretherick 1979

8.1 Compatibility of Acetic Acid with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Sodium Hydroxide	•						•							NFPA 1978
Sodium Peroxide			•										Explodes if not kept cold	NFPA 1978
p-Xylene			•										Detonating mixtures may be produced	NFPA 1978
CHEMICAL GROUPS														
Cyanides				•		•							Produces hydrogen cyanide	EPA 600/2-80-076
Epoxides	•				•									EPA 600/2-80-076
Explosives			•		•								Can decompose explosives resulting in enough heat to cause detonation	EPA 600/2-80-076
Metal Fluorides						•							Forms hydrogen fluoride	EPA 600/2-80-076
Metals		•		•									Generates hydrogen	EPA 600/2-80-076
Oxidizing Agents		•	•											Bretherick 1979

8.1 Compatibility of Acetic Acid with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Permanganates		•											Explosion if not kept cold	NFPA 1978
Sulphides	•		•			•							Generates hydrogen sulphide	EPA 600/2-80-076

9 COUNTERMEASURES

9.1 Recommended Handling Procedures

The following procedures have been derived from a literature review. To avoid any deviation from the intended meaning, the wording of the original source has been essentially unchanged - in so doing, it is recognized that there may be some discrepancies between different sources of information. It is recognized that countermeasures are dependent on the situation, and thus what may appear to be conflicting information may in fact be correct for different situations. The following procedures should not be considered as Environment Canada's recommendations.

9.1.1 Fire Concerns. Acetic acid is combustible but is not a flammable liquid (MCA 1951). It gives off flammable vapours which may form explosive mixtures with air (NFPA 1978).

9.1.2 Fire Extinguishing Agents. Use water spray to cool containers involved in a fire (GE 1980).

Small fires: Dry chemical, CO_2, water spray or foam (alcohol).

Large fires: Water spray, fog or foam.

Move containers from fire area if this can be done without risk. Avoid adding water inside containers; stay away from tank ends (ERG 1980).

9.1.3 Spill Actions.

9.1.3.1 General. Stop or reduce discharge of material if this can be done without risk. Eliminate all sources of ignition. Avoid skin contact and inhalation (Celanese MSDS 1979). If the leak or spill has not ignited, use water spray to disperse the vapours and to protect men attempting to stop the leak (GE 1980). Cellosize, an absorbent material, has shown possible applicability for vapour suppression and/or containment of acetic acid spills (ICI 1982).

9.1.3.2 Spills on land. Contain, if possible, by forming mechanical and/or chemical barriers to prevent spreading. Remove as much material as possible by pump or vacuum equipment. Cover the area with lime or sodium bicarbonate to neutralize the residual acid and shovel into containers for disposal (EPA 670/2-75-042; GE 1980).

9.1.3.3 Spills in water. Contain, if possible. Neutralize with sodium bicarbonate or lime (EPA 670/2-75-042; OHM-TADS 1981). Dowex 5WX4 might also be considered as

sorbent materials in spill situations (CG-D-38-76). Remove contaminated water for treatment as indicated below.

9.1.4 Cleanup and Treatment.

9.1.4.1 General. For treatment of contaminated water, gravity separation of solids followed by neutralization with sodium hydroxide is recommended. Further treatment is accomplished by passing the above treated water through dual media filtration (EPA 600/2-77-227).

The following treatment process has shown possible applicability for spill countermeasures (TSA 1980):

Process	Percent Removal
Reverse Osmosis	<20 to 80

Acetic acid can also be removed by treating the contaminated water with activated sludge (Metry 1980).

Narkis (1980) used a number of treatment methods on acetic acid-contaminated water. Ferric chloride removed an average of 9.5 percent and lime 14.9 percent. Carbon absorption did not show any appreciable removal. Kvo (1977) used ozonation combined with UV light to remove up to 92 percent of acetic acid in 2 hours. Successive oxidation of acetic acid produces glyoxylic acid, oxalic acid and ultimately carbon dioxide. Fang (1976) used reverse osmosis to remove acetic acid and achieved the following removal efficiencies with various membranes:

Membrane	Removal (%)
Polyamide	10-70
Polyethylenimine	50-70
Cellulose acetate	5-12
Cellulose triacetate	20
Cellulose acetate butyrate	4
Chlorinated polyphenylene	22

9.1.5 Disposal. Waste acetic acid must never be discharged directly into sewers or surface waters. Following treatment, either at the spill site or at a waste management facility, the resultant sludge can be disposed of to a secure landfill.

9.1.6 Protective Measures. For entry into a situation where the spilled material and its characteristics are unknown, self-contained breathing apparatus and a totally encapsulated chemical suit should be worn.

If the spilled material is known to be acetic acid:

- Response personnel should be provided with and required to use impervious clothing, gloves, face shields (20 cm minimum), and other appropriate protective clothing necessary to prevent any possibility of skin contact with solid or liquid acetic acid or solutions containing acetic acid (NIOSH/OSHA 1981).
- Dust- and splash-proof safety goggles are recommended where there is any possibility of solid or liquid acetic acid or solutions containing acetic acid contacting the eyes (NIOSH/OSHA 1981). Gas-tight and chemical safety goggles should also be considered (Celanese MSDS 1979).
- The following clothing materials are penetrated by acetic acid in time periods greater than 1 hour: butyl rubber, neoprene, nitrile, polyethylene, polyurethane, and PVC. The following materials showed penetration times of about 1 hour: natural rubber, neoprene with styrene-butadiene coating, nitrile with PVC coating, and styrene-butadiene rubber (Little 1983).
- Rubber high top safety shoes or boots, outer clothing fitted snugly at the neck and wrist, rubber aprons, and gloves should also be considered as protective clothing to be worn when handling acetic acid (GE 1980).
- The following chemical suit materials are recommended for protection against acetic acid (EE-20): cloropel, neoprene, PVC (excellent resistance) and butyl (good resistance).
- Nonimpervious clothing which becomes contaminated with solid or liquid acetic acid or solutions containing acetic acid should be removed immediately and not reworn until the acetic acid is removed from the clothing (NIOSH/OSHA 1981).
- Eye wash stations and chemical safety showers should be readily available in areas of use or spill situations (GE 1980).

The following is a list of the minimum respiratory protection recommended for personnel working in areas where acetic acid is present (NIOSH/OSHA 1981):

Condition	Minimum Respiratory Protection* Required Above 10 ppm
Vapour Concentration 500 ppm or less	Any chemical cartridge respirator with a full face-piece and an organic vapour cartridge(s). A gas mask with a chin-style or a front- or back-mounted organic vapour canister.

Condition	Minimum Respiratory Protection* Required Above 10 ppm
	Any supplied-air respirator with a full facepiece, helmet, or hood.
	Any self-contained breathing apparatus with a full facepiece.
1000 ppm or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greather than 1000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
	A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapours.
	Any escape self-contained breathing apparatus.

* Only NIOSH-approved or MSHA-approved equipment should be used.

9.2 Specialized Countermeasures Equipment, Materials or Systems

The following items are taken from a previous study (Dillon 1982) and should not be considered to be the only suitable specialized countermeasures equipment, materials or systems available. More details on the specifications, performance and availability of these items can be found in the referenced study.

Leak Plugging	Plug N' Dike®
Pumps for Liquids	U.S. Coast Guard ADAPTS
Treating Agents	Hazorb (Sorbent)

10 PREVIOUS SPILL EXPERIENCE

This section contains information on previous spill experience which will be useful to readers in understanding spill response and countermeasures. Only those which meet the criteria are included, and thus, the number of experiences is not an indication of the problems or frequency of spillage. As technology in spill control advances, this section will be updated in future manual revisions to include the most useful information.

11 ANALYTICAL METHODS

The general approach adopted for each of the Priority Chemicals was as follows.

Methods have been documented here for the analysis of samples from air, water and soil in a normally equipped chemical laboratory remote from the spill site. Customary sources of standard or recommended analytical methods were consulted, and outlines are presented for each chemical. These sources included publications of the U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. Environmental Protection Agency (EPA), the American Water Works Association (AWWA), the American Society for Testing and Materials (ASTM), and the American National Standards Institute (ANSI).

If the standard or recommended methods were judged to be reliable and specific enough for the analysis of environmental and materials samples from spill sites and if they do not require highly specialized laboratory equipment, no additional methods were sought.

If especially simple, reliable tests (e.g., commonly used industrial methods) were found, they have been presented as well.

11.1 Quantitative Method for the Detection of Acetic Acid in Air

11.1.1 Gas Chromatography (NIOSH 1977). A range of 12.5 to 50 mg/m^3 (5.1-20.4 ppm) of acetic acid in air may be determined by gas chromatography using flame ionization detection.

A known volume in air is drawn through a 7 cm x 6 mm O.D. charcoal tube containing 2 sections of 20/40 mesh activated charcoal separated by a 2 mm portion of urethane foam. The first section contains 100 mg whereas the second section contains 50 mg. A silylated glass wool plug is placed before the front absorbing section. A sample size of 168 L of air sampled at 1.0 L/min is recommended.

The charcoal tube sample is scored before the first section of charcoal and broken. The larger, or front, section of charcoal is transferred to a 2 mL stoppered sample container container 1.0 mL of formic acid. The same operation is performed with the back-up section. The sample should be allowed to desorb for 60 min. A 5 µL aliquot of sample is injected into a gas chromatograph equipped with a flame ionization detector.

The acetic acid is determined using an electronic integrator which measures peak area in conjunction with a calibration curve.

Typical gas chromatograph conditions are: a 1 m x 4 mm I.D. glass column packed with 60/80 mesh Carbopack B/3 percent carbowax 20 M/0.5 percent H_3PO_4, 60 mL/min nitrogen carrier gas, hydrogen gas flow at 50 mL/min, air flow at 500 mL/min, injector temperature at 230°C, detector temperature at 230°C, and the column temperature from 130 to 180°C at 10°C/min.

11.2 Qualitative Method for the Detection of Acetic Acid in Air

A range of 5 to 50 ppm of acetic acid in air may be determined using a Drager detector tube for acetic acid.

A known volume of air is drawn through a Drager detector tube for acetic acid using a Drager gas detector pump. A colour change of the bluish-violet indicating layer to yellow indicates acetic acid. The colour change is based on the reaction between acetic acid and an acid indicator in the reaction ampoule (Drager 1979).

11.3 Quantitative Method for the Detection of Acetic Acid in Water

11.3.1 Steam Distillation (AWWA 1981). A range of up to 5000 ppm of organic acids as acetic acid may be determined using steam distillation.

A minimum 1 L volume of representative sample is collected in an appropriate container and acidified to pH 3 with 50 percent sulphuric acid. A 6 mL volume of ferric chloride solution, prepared by dissolving 82.5 g ferric chloride solution, prepared by dissolving 82.5 g ferric chloride-hexahydrate in 1 L of distilled water, is added to the sample. A 50 g mass of diatomaceous-silica filter aide is added and the mixture is shaken. The sample is suction-filtered using a Buchner funnel containing a filter paper freshly coated with a thin layer of diatomacous-silica. The residue is washed four times with water and the filtrate adjusted to pH 11 with sodium hydroxide solution. The sample is concentrated to 150 mL on a steam bath and refrigerated. The cooled filtrate is adjusted to pH 4 with 50 percent sulphuric acid and transferred to a suitable distilling flask. Magnesium sulphate is added to slight excess and heat is applied to a steam generating flask connected to the distilling flask. A distillate volume of 200 mL is collected in approximately 25 min. The distillation rate is increased and a total of 500 mL of distillate is collected.

The acetic acid is determined by titration with 0.1 N sodium hydroxide using phenolphthalein indicator.

11.4 Qualitative Method for the Detection of Acetic Acid in Water

The sample is collected as in Section 11.3.1. A one drop volume of sample is combined with 50 mg of solid sodium bicarbonate dissolved in 1 mL of water. The mixture is shaken gently. Vigorous effervescence or steady evolution of gas indicates a carboxylic acid (Owen 1969).

11.5 Quantitative Method for the Detection of Acetic Acid in Soil

11.5.1 Gas Chromatography (NIOSH 1977; ASTM 1979). Concentrations of acetic acid at the ppm level may be detected using a flame ionization detector.

Approximately 20 g of soil, accurately weighed, are collected in a glass jar. Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane) is used to extract acetic acid from the soil. The Freon® is distilled from the reaction flask on a water bath at 70°C.

Sample loss may be a problem if the temperature is not carefully controlled. Air is drawn through the flask for the final minute to remove all traces of the Freon®. The residue is dissolved in carbon disulphide.

A suitable aliquot of the dissolved residue is injected into a gas chromatograph equipped with a flame ionization detector. The acetic acid is determined using an electronic integrator which measures the area under the peak in conjunction with a calibration curve.

11.6 Qualitative Method for the Detection of Acetic Acid in Soil

The sample is collected as in Section 11.5.1 and extracted using Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane). The Freon® is distilled from the reaction flask on a water bath at 70°C. Air is drawn through the flask for the final minute to remove all traces of the Freon®. The residue is dissolved in water. A one drop volume of sample is combined with 50 mg of solid sodium bicarbonate dissolved in 1 mL of water. The mixture is shaken gently. Vigorous effervescence or steady evolution of gas indicates a carboxylic acid (AWWA 1981; Owen 1969).

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